JOURNAL of the AMERICAN SOCIETY *of* *NAVAL ENGINEERS* Inc.

May, 1961

Volume 73 Number 2

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1951 **Rear Admiral Louis Dreller, U. S. Navy, Ret.**
1952 **Rear Admiral T. C. Lonnquest, U. S. Navy**
1953 **Rear Admiral Homer N. Wallin, U. S. Navy**
1954 *Rear Admiral Evander W. Sylvester, U. S. Navy*
1955 **Rear Admiral W. D. Leggett, Jr., U. S. Navy**
1955 **Rear Admiral F. R. Furth, U. S. Navy**
1956 **Rear Admiral Kenneth K. Cowart, U.S.C.G.**
1957 **Rear Admiral Albert G. Mumma, U. S. Navy**
1958 **Rear Admiral Leroy V. Honsinger, U. S. Navy**
1959 **Rear Admiral William A. Dolan, U. S. Navy**
1960 **Rear Admiral Robert E. Cronin, U. S. Navy**

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*Names in italics deceased

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of

The American Society of Naval Engineers, Inc.

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SEVENTY-THIRD YEAR

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MAY, 1961

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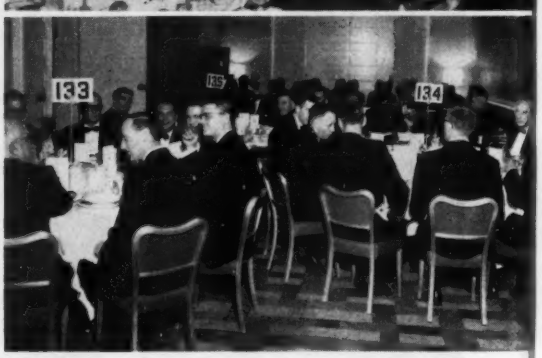
Official U. S. Coast Guard Photos

The Speaker's Table During the President's Welcome
From left to right: Admiral Furth, Admiral Hubbard, Admiral Lonnquist, Admiral Peltier, Admiral Mumma, Mr. Fessenden, Admiral Williams Admiral Robbins, Mr. Herr, Admiral Wilson, Mr. Newell, Admiral Burke, Admiral Will, Admiral Thiele, Captain Smith, Admiral Cronin, Mr. Allen, Admiral James, Admiral Cowart, Admiral Stroop. Chaplain Cleaves and the toastmaster are standing behind Admiral Thiele.



Right: Top—General view from the South end of the Congressional Room
Center—General view of the Federal Room overflow.
Bottom—More of the overflow in a foyer.

1961 Annual Banquet

Left: Part of the overflow on the mezzanine.

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VOLUME 73 MAY 1961 NUMBER 2

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NAVAL ENGINEERING

Definition: NAVAL ENGINEERING is the art and science applied in the design, construction, operation and maintenance of naval ships and their installed equipment.

SECRETARY'S NOTES

The Annual Banquet

On Friday, the 28th of April, 1745 Society members and guests gathered for the Society's 43rd annual banquet. The scene was the second floor of the Statler Hilton Hotel in Washington, D. C.

Prior to and after the banquet members and guests gathered in some 60 hospitality spots where old friendships were renewed, new ones made, reminiscences exchanged and new ideas advanced. The generosity of the hosts at these various parties provides one of the most attractive features of our gatherings and the Society owes them a debt of gratitude for their, not always recognized, contributions.

Official U. S. Coast Guard Photo

Speaker's Table: Seated from left to right: Admiral Hubbard, Admiral Lonnquest, Admiral Peltier, Admiral Mumma, Mr. Fessenden, Admiral Williams, Admiral Robbins, Mr. Herr, Admiral Wilson, Mr. Newell, Admiral Burke, Admiral Will, Admiral Thiele.

As is customary, the entire affair was conducted with a minimum of formality. Only that which was necessary to insure an interesting and fast moving but ample program was enforced.

The entire staff of the Statler Hilton maintained its reputation of excellent and efficient service. Their arrangements, in every detail, made for a very successful party from a material point of view. Excellent dinner music was provided by a contingent of the Navy band.

The various highlights of the banquet are covered in greater detail and a few candid photographs of the affair will be found in other places in these notes.

After the convocation was delivered by Chaplain R. D. Cleaves, USN, the President opened the program by reading the following telegram:

"TEMPORARY WHITE HOUSE
NEW YORK, N.Y.
APRIL 28

REAR ADMIRAL EDWARD H. THIELE, PRESIDENT
AMERICAN SOCIETY OF NAVAL ENGINEERS

IT IS A PRIVILEGE TO EXTEND CONGRATULATIONS TO THE AMERICAN SOCIETY OF NAVAL ENGINEERS ON YOUR 73RD ANNIVERSARY. THE HISTORIC PERFORMANCE OF OUR NAVAL SHIPS IN WAR AND PEACE GIVES A SPLENDID TESTIMONY TO THE ENTERPRISE AND VITALITY OF OUR ORGANIZATION. SINCERE BEST WISHES TO ALL OF YOU WHO ARE PARTICIPATING IN THIS ANNUAL EVENT.

JOHN F. KENNEDY"

At the speaker's table were a few of the distinguished guests who were present. Others were scattered among the 140 odd tables. Space prevents inclusion here of a complete list of those who attended. Those at the head table were:

Admiral Arleigh Burke, USN, Chief of Naval Operations

Admiral J. M. Will, USN, Retired, President of American Export Lines and the principal speaker

Rear Admiral Miles H. Hubbard, USN, Assistant Chief of Naval Operations for Logistics

Captain Levering Smith, USN, The recipient of the ASNE 1960 Gold Medal Award

Mr. John R. Newell, President of the Society of Naval Architects and Marine Engineers

Rear Admiral P. D. Stroop, USN, Chief of the Bureau of Naval Weapons

Rear Admiral R. K. James, USN, Chief of the Bureau of Ships

Rear Admiral E. J. Peltier, CEC, USN, Chief of the Bureau of Yards and Docks

Rear Admiral T. H. Robbins, Jr., USN, Commandant of the Potomac River Naval Command

Mr. Uriah L. Allen, Jr., Founder of the Flagship Section

Mr. Arthur G. Fessenden, Honorary Member

Mr. Donald L. Herr, Honorary Member

Admiral R. E. Wilson, USN, Retired, Member of the Maritime Commission

Commander Richard D. Cleaves, ChC, USN

Rear Admiral E. H. Thiele, USCG, President of the American Society of Naval Engineers;

The following past-Presidents of the Society:

Rear Admiral Henry Williams, USN, Retired, President in 1940

Rear Admiral T. C. Lonnquest, USN, Retired, President in 1952

Rear Admiral F. R. Furth, USN, Retired, President in 1955

Rear Admiral K. K. Cowart, USCG, Retired, President in 1956

Rear Admiral A. G. Mumma, USN, Retired, President in 1957

Rear Admiral R. E. Cronin, USN, President in 1960

Present but of their own choice not at the speaker's table were Rear Admiral Louis Dreller, USN, Retired, President in 1951 and Rear Admiral D. W. Leggett, USN, Retired, President in 1955

The program consisted of only four events after dinner and after the Society's guests were introduced:

The presentation by the President of the Society's first charter to a local chapter to Mr. Uriah L. Allen for the Flagship Section;

The presentation of the Annual ASNE Gold Medal for the outstanding Naval Engineering achievement of 1960 by Admiral Cronin and the accompanying life membership by the President to Captain Levering Smith, USN;

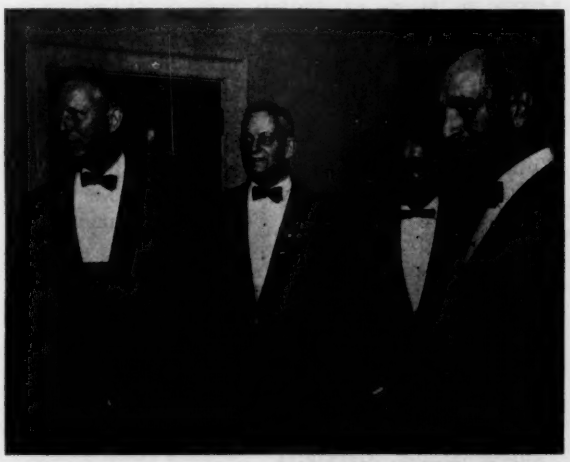
A short informal talk by Admiral Burke; and the Principal Address by Admiral Will

All of these are covered separately in or following these notes.

It is the opinion of those who have attended many banquets that this in 1961 was the peer of any of it's predecessors. The Society is grateful to all who attended as well as to all of those who were responsible for the arrangements for this success.

Official U. S. Coast Guard Photo

Mr. Blunck, Admiral Thiele, Admiral Wilson



Official U. S. Coast Guard Photo

Admiral Burke with Rear Admirals Mumma, Furth and Thiele

Local Chapters

In 1952 the By-Laws were amended to permit local chapters to be chartered by the Society. Several inquiries were made from different locations but nothing materialized until Mr. Uriah L. Allen, a 10 year member from Silver Spring, Maryland became interested. Mr. Allen works in Baltimore for The Westinghouse Electric Company but living in a suburb of Washington his efforts extended into both the Baltimore and Washington areas. The result is the Society's FIRST local chapter. It has been chartered for the Washington-Baltimore area and is authorized to be called THE FLAGSHIP SEC-

Official U. S. Coast Guard Photo

The President presents the charter of the Flagship Section of ASNE to Mr. Uriah Allen who organized this local Chapter

Official U. S. Coast Guard Photo

Mr. Vitucci, Mr. Allen, Mr. Fauquier, Admiral Burke, Mr. Newell

TION of ASNE. The thirty-six charter members of this chapter are:

Mr. Uriah L. Allen, Mr. J. A. Bauman, LCDR J. M. Beggs, USNR, Mr. Rupert A. Blue, Mr. Buford M. Brown, LTJG Mario P. Ciagamaglia, USNR, John H. Clotworthy, CAPT. V. E. Day, USCG, LCDR R. F. Dodd, USNR, LT C. H. Donelson, USNR, Mr. C. W. Doremus, Mr. H. E. Ellerman, Mr. R. L. Elliott, Jr., Mr. Harold D. Ellrod, LT W. D. Gerich, USNR, Mr. F. E. Gignoux, Mr. T. H. Glenn, Mr. H. F. Hathaway, Mr. I. G. Herman, RADM C. M. E. Hoffman, USN (Ret), Mr. P. G. Hughes, Mr. William H. Jory, Robert E. Kirby, CDR William E. Lehr, USNR, Mr. James C. P. Long, Mr. C. L. Malinow, Mr. Nicholas V. Petrou, William E. Radzykewycz, Mr. W. W. Reid, Mr. R. S. Sanford, CDR C. F. Scharfenstein, Jr., USCG, Mr. Frank J. Smollon, Mr. Carl L. Suhrstedt, LCDR R. L. Tate, USNR, Mr. A. P. Veltre, Mr. R. E. Wingquist.

Any member of the Society who is interested in joining the Flagship Chapter should write to—

Mr. Uriah L. Allen, Jr.
12116 Bluhill Road
Silver Spring, Maryland

Any member in any area who is interested in organizing a local chaper is referred to the rules which are printed below. The Secretary-Treasurer will be happy to furnish copies of Mr. Allen's letter which was very effective as the results show. A copy of the By-Laws of the FLAGSHIP SECTION will also be furnished as a guide to anyone interested.

It is hoped that before long local ASNE chapters will blanket the country. These activities should become a lively source of new members of the Society and of fresh manuscripts for the Journal.

Rules For Local Chapters

For the information of any member who intends to follow Mr. Allen's lead and form a local chapter of ASNE the rules which were adopted by the Council in 1952 and which are still in effect are quoted below:

"a) Twenty or more regular members, Naval or Civilian, may apply for a charter as a local Chapter.

b) Each application must be accompanied by a list of members and a copy of local By-Laws. The latter must meet the following minimum requirements:

1. All financial dealings of the local Chapter must be independent of the Society and can in no way obligate the Society as a whole. The Local Chapter shall be set up on a non-profit basis. All accounting shall be local.
2. Each active local Chapter shall receive from the Society a grant of $0.50 per year for each naval member, civil member, associate member, junior member or student member who resides in the local area and who associates himself with the local Chapter.
3. Any technical papers presented at local chapter meetings, shall be submitted to the Secretary-Treasurer of the Society for consideration for publication in the JOURNAL. Any paper accepted will be paid for at regular rates.
4. Each local chapter shall submit a quarterly report of its activities to the Secretary-Treasurer. These reports must reach Washington, D. C., prior to 15 January, 15 April, 15 July and 15 October. This report shall contain a list of active local members as of the first day of the quarter for the purpose of computing the annual grant.
5. Associate, Junior and Student members of the Society shall be eligible for membership in a Local Chapter, entitled to all the privileges of other members except voting for and holding office in the Parent Society."

The February Issue—ERRATA

We believe that the entire gamut of human error in the publishing business is exemplified in the February 1961 issue of the JOURNAL. The probable reason is that difficulties developed in the printer's plant and in the final fight to meet a deadline, some checking and proof reading were done too hurriedly for effectiveness. We have made such amends as are possible to each of those who is affected by any of the mistakes. To provide a more general cleaning up, the following errata are published:

The Dolphin's Secret by Dr. Max O. Kramer page 103

The manuscript and galley proof of this article included the references which are cited in the article. In the final printing they disappeared from page 107 where they belonged. This would have looked like this:

REFERENCES

[1] Gero, D. R. "Power and Efficiency of Large Salt Water Fish," *Aeronautical Engineering Review*, January 1952.
[2] Gray, James, "How Fishes Swim," *Scientific American*, August 1951.
[3] Kramer, Max O., "Boundary Layer Stabilization by Distributed Damping," *Journal of the Aeronautical Sciences*, Vol. 24, No. 6, June 1957.
[4] Kramer, Max O., "Boundary Layer Stabilization by Distributed Damping," JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS, February 1960.

New Gyros for Our Submarines, by Frederick D. Braddon, republished from the *Journal of the Franklin Institute,* page 121.

In preparing the Acknowledgment, a footnote was overlooked and thus the article carried no information as to the identity of the author. Mr. Frederick D. Braddon at the time of writing was Chief Engineer, Marine Division, Sperry Gyroscope Company, Syosset, New York. He is now Technical Assistant to the Vice President for Engineering, Sperry Gyroscope Company, Great Neck, New York.

Quick Ballasting/Deballisting in LSD, by Lieutenant Commander L. O. Chirillo, USN, page 191.

Two literal errors were printed in this article. The author's middle initial is O and not D. Figure 1 on page 192 is of an LSD, not an LST.

Student Memberships, Secretary's Notes, page 9.

The entire list of schools whose undergraduate students are eligible for Student Membership in the Society is in three sections. Only one of these was listed in the February issue. The complete list is as follows:

Government Service Academies

U.S. Air Force Academy
U.S. Naval Academy
U.S. Military Academy
U.S. Coast Guard Academy
U.S. Merchant Marine Academy

Official U. S. Coast Guard Photo

Captain Reese, Mr. Vittucci, Mr. Newell, Mr. Redmon, Captain Smith

California State Maritime Academy
Maine State Maritime Academy
New York State Maritime Academy
Massachusetts Maritime Academy

Colleges and Universities with NROTC Units

Auburn University
Brown University
University of California
University of Colorado
Columbia University
Cornell University
Dartmouth College
Duke University
Georgia Tech.
Harvard University
Holy Cross
University of Idaho
University of Illinois
Iowa State University
University of Kansas
University of Louisville
Marquette University
Massachusetts Institute of Technology
Miami University
University of Michigan
University of Minnesota
University of Mississippi
University of Missouri
University of Nebraska
University of New Mexico
University of North Carolina
Northwestern University
University of Notre Dame
Ohio State University
University of Oklahoma
Oregon State College
University of Pennsylvania
Pennsylvania State University
Princeton University
Purdue University
Rensselaer Polytechnic Inst.
The Rice Institute
University of Rochester
University of South Carolina

University of Southern California
Stanford University
University of Texas
Tufts University
Tulane University
University of Utah
Vanderbilt University
Villanova University
University of Virginia
University of Washington
University of Wisconsin
Yale University

Engineers Council Listing of Accredited Schools

University of Akron
University of Alabama
University of Alaska
University of Arizona
University of Arkansas
Bradley University
Polytechnic Institute of Brooklyn
Bucknell University
California Institute of Technology
Carnegie Institute of Technology
Case Institute of Technology
Catholic University of America
University of Cincinnati
The Citadel
Clarkson College of Technology
Clemson Agricultural College
Colorado A&M College
Colorado School of Mines
University of Connecticut
Cooper Union School of Engineering
University of Dayton
University of Delaware
University of Denver
University of Detroit
Drexel Institute of Technology
Fenn College
University of Florida
George Washington University
University of Hawaii
University of Houston
Howard University
Johns Hopkins University
Kansas State College
University of Kentucky
Lafayette College
Lehigh University
Louisiana Polytechnic Institute
Louisiana State University
Lowell Technological Inst. of Mass.
University of Maine
Manhattan College
University of Maryland
University of Massachusetts
Michigan College of Mining and Technology
Michigan State College
Mississippi State College
Missouri School of Mines
Montana School of Mines
Montana State College
University of Nevada
University of New Hampshire
New Mexico College of A&M Arts
New York City College
New York State College of Ceramics
New York University
Newark College of Engineering
North Carolina State College
North Dakota Agricultural College
University of North Dakota
Norwich University
Ohio University
Oklahoma A&M College
University of Pittsburgh
Pratt Institute
University of Rhode Island
Rose Polytechnic Institute
Rutgers University
Saint Louis University
University of Santa Clara
South Dakota State College
South Dakota School of Mines
Southern Methodist University
Stevens Institute of Technology
Swarthmore College
Syracuse University
University of Tennessee
A&M College of Texas
Texas College of Arts and Industries
Texas Technological College
Texas Western College
Toledo University
University of Tulsa
Union College
Utah State Agricultural College
University of Vermont
Virginia Polytechnic Institute
State College of Washington
Washington University
Wayne University
Webb Institute of Naval Architecture
West Virginia University
Municipal University of Wichita
Worcester Polytechnic Institute
University of Wyoming

Official U. S. Coast Guard Photo

Mr. Herr, Admiral Thiele, Commander Thornbury, Admiral James, Admiral Peltier

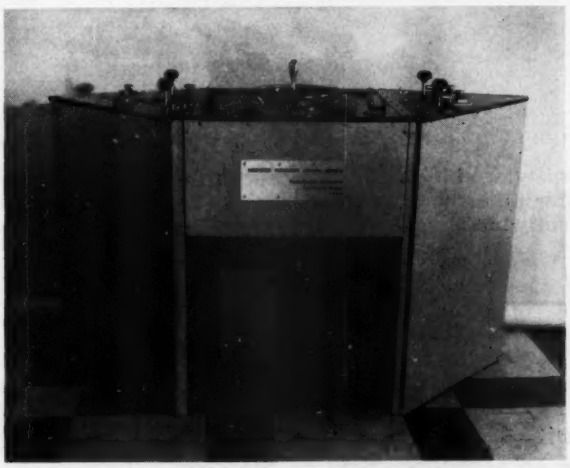
Members—Personal Notes

We have not made a practice, nor does space make it possible, to carry all of the personal notes which are made available to us to show the activities of all members. However, because of specific service which they have rendered to the Society, some things are worthy of recording in the JOURNAL. We have selected a few of these.

Captain Robert B. Madden, USN, Retired

Captain Madden served the Society for eight years as Assistant Secretary-Treasurer. The outstanding character of his service is a matter of record. Captain and Mrs. Madden have just completed an extended trip to the Orient. This is indoctrinal to the position which he assumed in March 1961, shortly after his retirement from active Navy duty, as Assistant to the Vice President for Engineering of American President Lines. Captain Madden's office is located in San Francisco.

Mr. Robert Taggart



Integrated Propulsion Control Console

Mr. Taggart joined the Society in 1948 and has been one of our more effective authors in many issues of the JOURNAL. His name will be noted on the name plate which shows in the above photograph.

Project Mohole, an undertaking of the National Academy of Science, The National Research Council and the National Science Foundation, has been given more general publicity than is accorded to most ventures of this kind. Many of these have not credited Mr. Taggart's part in it.

Project Mohole's purposes is the exploration of the earth's crust to learn the truth of its composition and to test the theories which have been advanced in regard to it. Because of the depth of the layer of interest under the continents, the most approachable locations underlie the oceans where this layer is much closer to the sea bottom by thousands of feet than it is to any continental surface. A mere two miles of water overlies it.

The disciplines which are required to help in a problem of this sort are many because the individual problems are many. It is not our intention to try to cover the entire endeavor—only that portion of it which an active ASNE member undertook to accomplish and did.

This problem is to hold the drilling rig vertically above the hole that is being drilled in earth with a separation between rig and hole of more than 11,000 feet of sea water—fluid and movable at the will of wind and tide and ocean currents. Between the rig and hole is a continuous length of drill pipe. In a length of 11,000 feet this pipe could withstand vertical separation of its fixed ends by 600 feet, possibly 1,000, but no more. The rig rides on a buoyant barge which will certainly move with the surface water and presents a considerable sail area to the wind.

There are three elements in the maintenance of the needed position vertically above the hole in spite of contrary forces. These are:

Intelligence—Knowledge of actual position relative to desired position

Means—of changing the position and

Agency—to use the means for improving the position.

The intelligence is furnished by an array of buoyed radar and sonar targets reflected in scopes in front of the operator who is the agent. The means is the Taggart devise. By natural movement of the joy stick which can be seen in the photograph the operator controls the action of four heavy Murray Tregurtha outboard engines which are mounted on the four corners of the barge. The ingenious control circuitry permits delicate movements of the barge with its heavy load, in either translation or rotation.

In the test drilling which has been done to date, as was described by John Steinbeck in the 14 April 1961 issue of *Life* Magazine, the earth was penetratted more than 500 feet under 11,000 feet of water from a barge on the surface riding a heavy and stormy sea. The Taggart controls held the rig within a 200 feet circle providing a more than adequate margin of safety against losing the drill.

Captain Ivan Monk, USN, Retired

Captain Ivan Monk, USN (Ret.), a member of the Society's Council in 1958 and 1959 has joined De Laval Steam Turbine Company, Trenton, N. J., and became Manager of the Service and Repair Department in April. He will succeed J. W. Robinson, who retired March 31 after 49 years with De Laval. At the time of his recent retirement, Captain Monk was Director of the Machinery Division, Bureau of Ships. He has also headed the BuShips aircraft carrier and turbine and gear branches, and has been Design Superintendent of the New York Naval Shipyard. He has also been Chief Engineer of the USS *Princeton* and other ships. He holds the Legion of Merit and the Bronze Star.

Mr. Herman S. Prieser

Mr. Prieser, a frequent contributor to the JOURNAL has left government service in the Navy Department's Bureau of Ships and is now President and Technical Director of Chemionics Engineering Laboratories, Inc., Bala-Cynwyd, Pa.

Miss Ruth M. Leonard, Administrative Director of the Society at her desk with the President, Secretary-Treasurer and her assistant, Mrs. Twila Ellis.

Council members present at the February meeting. Left to right: Front row: Secretary-Treasurer; Admiral Thiele, President; Mr. Hill, Mr. Weber. Back Row: Lieutenant Commander Roane, Captain Jones, Admiral Schultz and Captain Schumacher.

The above pictures were taken for the purpose of displaying the offices of the Society. For this purpose, the project was not very successful. However, they do offer to members to whom the office is not readily accessible, a vicarious introduction to those who are currently directing the affairs of the Society.

The United States Maritime Administration has signed a contract with Stanford Research Institute to prepare an economic study on the commercial potentiality of hydrofoil craft. The contract calls for completion of the study in six months at an estimated cost of $60,000. An experimental 104-ft 80-tons hydrofoil vessel is being built for the Maritime Administration on Long Island, N.Y., by Grumman Aircraft Engineering Corporation, and present schedules call for the craft to be ready for tests in mid-1961. The objective of the study will be to identify trade routes of interest to the Maritime Administration for hydrofoil operations, and to evaluate both the economic and operational feasibility of future commercial hydrofoil craft. The routes studied will be restricted to those which could be served by "first generation" hydrofoil craft. These are assumed to be limited to maximum speeds of some 60 or 70 knots, a weight of about 500 tons, and a cruising range of between 500 and 1,000 nautical miles. Doubtless study will be made of the hydrofoil services already in commercial operation in the Bay of Naples, the Straits of Messina, Lake Maggiore, in the Baltic and on Lake Maracaibo.

—from THE SHIPPING WORLD
February 15, 1961

1960 A.S.N.E. GOLD MEDAL AWARD

CAPTAIN LEVERING SMITH, U.S. Navy

After receiving the ASNE Gold Medal Award from Rear Admiral R. J. Cronin, USN, and a Life Membership Certificate from Rear Admiral E. H. Thiele, USCG, Captain Smith made the following acceptance speech:

Members of the American Society of Naval Engineers:

I am most grateful to the American Society of Naval Engineers for its Gold Medal Award for 1960.

I am particularly grateful for the honor done through me to the members of the Navy-Industry Team developing and producing the POLARIS Fleet Ballistic Missile System.

The members of that Team have had much for which to be grateful:

For a dynamic, resourceful, demanding and inspiring Project Officer;

For a clear, concise, unambiguous objective of such undeniable importance to our Navy, our Nation and indeed to all mankind that all the hours we are physically capable of devoting to its fulfillment are not burden;

For wives and families who so appreciate this objective that they become members of the team by assuming many of our normal duties;

For a technical and management task of such scope and complexity as to call for use of all our knowledge and demand our very best judgment and skill;

For the opportunity and encouragement to analyze and understand all the relationships of our task to its objective in order that appropriate compromises may be made;

For the opportunity, the organization and the challenge to demonstrate that a democratic society respecting human dignity and individual liberties can decide upon and fulfill major objectives at least as rapidly as dictatorships;

For the burden of responsibility placed on us by the confidence and support of our Nation given long before we had a single submarine or missile to show for our efforts.

While these are matters we are properly grateful for, they are also challenges. We have made good progress, but we continue to confidently strive to meet our goal of providing the Fleet with 45 submarines armed with 2500 mile POLARIS Missiles. Hence, these challenges remain with us, and tonight, with this inspiring Gold Medal Award, you have added a challenge to act in the future as you have seen us act in the past.

I thank you for this new challenge.

ASNE AWARD WINNER

CAPTAIN LEVERING SMITH, U.S. Navy

Born in Joplin, Missouri, on March 5, 1910, Captain Smith attended High School in Grafton, Illinois, and Hall's Preparatory School, Columbia, Missouri, before his appointment to the U. S. Naval Academy in 1928. He was graduated and commissioned Ensign on June 6, 1932, and subsequently advanced to the rank of Captain, to date from January 1, 1951.

Upon graduation from the Naval Academy in June, 1932, he was assigned to the USS *TEXAS*, and served in the Gunnery, Communications and Engineering Departments of that battleship until August, 1936. He then assisted in fitting out the USS *SHAW* and served as that destroyer's First Lieutenant from her commissioning in April, 1937, until May, 1938. He was a student at the Naval Postgraduate School, Annapolis, during the next two years, and upon completion of the course in Ordnance, was assigned to the Bureau of Ordnance, Navy Department, Washington, D.C., where he served from September, 1940, until June, 1941, in the Magnetic Range Subsection.

In July, 1941, he joined the USS *BULMER* as Gunnery Officer, and after the outbreak of World War II in December of that year served as her Executive Officer until April, 1942. He subsequently served as Gunnery Officer on the Staff of Commander Destroyer Squadron 29, as Flag Lieutenant on the Staff of Commander Task Force 17, and as Chief Staff Officer to Commander Task Force 67. He participated in eleven campaigns and engagements in the Pacific including the battles of Santa Cruz, Lunga Point, and Philippine Sea, while on staff duty as Gunnery Officer of the USS *INDIANAPOLIS* from April, 1943, until September, 1944, and also survived the sinkings of the USS *HORNET* and USS *NORTHAMPTON*, on October 26, 1942, and December 1, 1942, respectively.

Returning to the Navy Department, he served from September, 1944, until September, 1947, as Head of Rocket Propellant, Pyrotechnic, and Chemical Warfare Subsection of the Research and Development Division, Bureau of Ordnance. In October, 1947, he reported to the U. S. Naval Ordnance Test Station, Inyokern, California, as Deputy Head of the Explosives Department, and later served as Head of Rockets and Explosives Department, and Associate Technical Director. In January, 1951, when promoted to the rank of Captain, he was designated for Engineering Duty (Ordnance).

Detached from the Naval Ordnance Test Station in April, 1954, he assumed command in May of the Naval Ordnance Missile Test Facility, White Sands Proving Ground, New Mexico, where he also served as Navy Deputy to the Commanding General until April, 1956. He then returned to the Bureau of Ordnance (Special Projects Office), to serve as Head of the Propulsion Branch. In December, 1956, he was designated Deputy Director, Technical Division, Special Projects. In June, 1957, he took over duties as Technical Director of Special Projects.

For his work on the POLARIS fleet ballistic missile weapon system program, he was awarded the Distinguished Service Medal on January 5, 1961.

The citation accompanying the DSM read in part: ". . . with keen foresight, early pioneering and undeviating determination, Captain Smith directed early emphasis on advancing the 'state-of-the-art' of solid propellant development. Breakthroughs resulting from his efforts provided one of two major scientific advances needed in conception of the FBM system. His superb grasp and direction of many diverse technical ramifications were signally responsible for acceleration obtained in the FBM program."

In addition to the DSM, Captain Smith has the American Defense Service Medal; the Asiatic-Pacific Campaign Medal; American Campaign Medal; World War II Victory Medal; and National Defense Service Medal.

Married to the former Beulah W. Lewis, of Mesilla Park, New Mexico, he currently resides at 5041 Waggaman Circle, McLean, Virginia.

The American Society of Naval Engineers

takes pleasure in presenting the ASNE Award for 1960

to

CAPTAIN LEVERING SMITH, U. S. NAVY

for contributions as set forth in the following

CITATION

"For outstanding service in the furtherance of the science of Naval Engineering as Technical Director, Special Projects Office. Initially pioneering in the provision of solid propellant ballistic missiles for use in submerged submarines, Captain Smith's responsibilities were subsequently extended to encompass the technical direction of the entire submarine weapon system development and installation. The scope, magnitude, and time scale of the effort represented by these responsibilities created an individual challenge unique in magnitude and of unsurpassed complexity in the annals of naval engineering. Captin Smith's keen scientific insight, extraordinary engineering skill, and industrial management competence guided the development and production of intricate and novel equipments and their assembly into revolutionary men-o-war. The courage, conviction, and integrity of his leadership are in great measure responsible for the timely delivery of the Fleet Ballistic Missile Weapon System to the service of the United States and the Free World."

Captain Smith pioneered in the introduction of solid propellant ballistic missiles in submarines at the inception of the POLARIS Program. His personal contributions were many in the advancement of this aspect of FBM Weapon System and the establishment of a "first" in the successful underwater launch of such large missiles.

Subsequent to these early endeavors, and after leading the definition of design parameters for formulating the ship characteristics for this entirely new type submarine, Captain Smith's responsibilities were extended to encompass the technical direction of the entire Weapon System development and installation for shipboard use. As Technical Director, Special Projects Office, his contributions included the direction of the effort to produce a revolutionary navigation subsystem which permits previously unheard-of ship position accuracies over extended periods without exposure of the submarine. He guided the missile fire control development and production to provide POLARIS submarines with equipment giving an entirely new dimension to ship borne weapons. His personal guidance and direction at crucial points immeasurably contributed to the missile design. His leadership also provided for the installation of novel communication equipment to meet new and demanding requirements of these ships.

In achieving this new era of sea power, Captain Smith's vision, wisdom, and judgment were essential. His keen scientific insight was necessary in ever gauging the state-of-the-art in many different disciplines so as to spur efforts toward success without hinging the design upon the impossible. His broad experience and skill were vital in the technical and managerial leadership which marshalled the resources of government and industry with balanced emphasis. The ships and their equipment were diverse and complex, and their schedules ever accelerating, yet in large measure due to the efforts of Captain Smith, the promised sailing dates were met for Fleet Ballistic Missile Submarines.

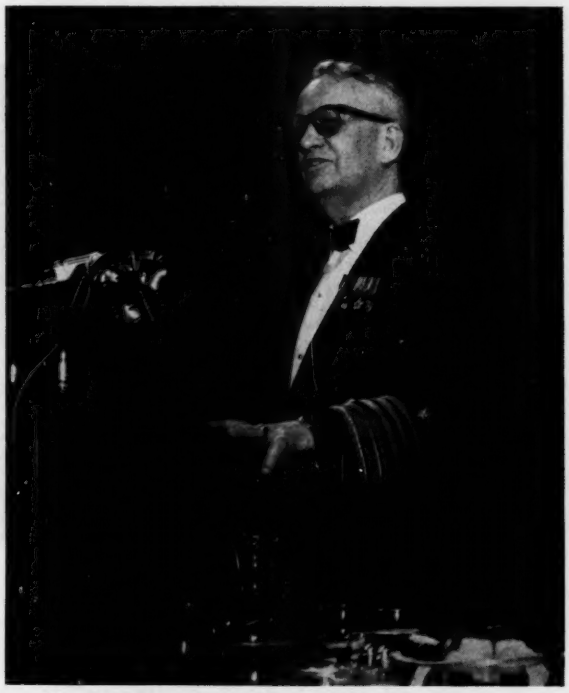
A. S. N. E. 1960 GOLD MEDAL AWARD

Rear Admiral Thiele presents the Life Membership Certificate to Captain Smith.

Left: Top—Captain Smith with Admiral Burke.
Center—Captain Smith prepares to acknowledge the Award.
Bottom—From left to right: Admiral Burke, Mr. Herr, Chaplain Cleaves and Captain Smith.

Captain Smith and Rear Admiral Cronin who presented the medal.

ADDRESS BY ADMIRAL ARLEIGH BURKE, USN, CHIEF OF NAVAL OPERATIONS, BEFORE THE AMERICAN SOCIETY OF NAVAL ENGINEERS—WASHINGTON, D.C.—28 APRIL 1961.



ADMIRAL ARLEIGH BURKE, USN

It is a great honor to be with you this evening. The American Society of Naval Engineers and the United States Navy have been partners for a long time. And I particularly welcome this opportunity to re-emphasize and to reaffirm the close bonds which exist between us. For we in the Navy are keenly aware of the many contributions your Society has made to the development of American seapower.

The Navy and naval engineering have grown strong together, in close association. Ours has been a relationship of mutual respect based on the frank recognition of the problems we share, and on our combined and cooperative efforts in the solution of naval problems. And this same spirit must characterize our efforts as we look to the future.

Our Navy stands in the midst of revolutionary changes. New weapons, new equipment and new techniques are being introduced into the Fleet as quickly as time and money will allow. As you can well imagine, this modern technological revolution and its effect on our naval forces have presented us with many difficult problems. And world events have given a new urgency to the solution of these problems.

American seapower is a basic element of Free World strength. For in many areas of the world, most of the men and material needed to answer the threat of military aggression would have to be brought in by sea. Our combat troops would have to depend on the sea for support, for air cover, for supplies and logistics. Our marines, our soldiers, and our airmen and our allies would have to look to the sea for the things they need to sustain them ashore. And this means that we must have naval forces, effective naval forces, fully capable of performing a wide range of combat functions—from amphibious assault to nuclear retaliation.

But seapower relies on far more than ships and weapons systems. Our capability to exert effective naval power when and where we need it rests on our natural assets of geography and material resources. It depends too on our shipbuilding capacity, and it rests very heavily on the technical and design skills of our naval engineers. Seapower includes **all** those things which enable a nation to use the sea advantageously, during peace or war.

But these are just the natural and human resources that make seapower possible. Even these important advantages can only be made effective by a nation whose people are aware of the opportunities offered by the sea. The unique advantages of seapower can only be exploited by a nation whose citizens understand how to **use** their maritime assets in their own national interest.

As we turn our minds and our hands to the difficult tasks which lie ahead, we must recognize clearly that we are engaged in the most serious competition we have ever faced in the life of our nation. It will take determination, hard work and conscientious effort to succeed in this all-out competition. That is why it is up to all of us, up to you and to me to set a new pace of effort, to set new records of achievement. We must establish new standards of performance in everything we do, in the military, in science and in education. Excellence must be the watchword—at sea, in business, and in our engineering and technical skills.

Our position as the leader of the Free World has been challenged. Only by meeting this challenge boldly, with courage, with vigor and with the will to win—today, tomorrow and always—can we succeed. Only by seizing our responsibilities, only by facing each of our problems squarely and overcoming them, can we further the great enterprises of our nation and of free men everywhere.

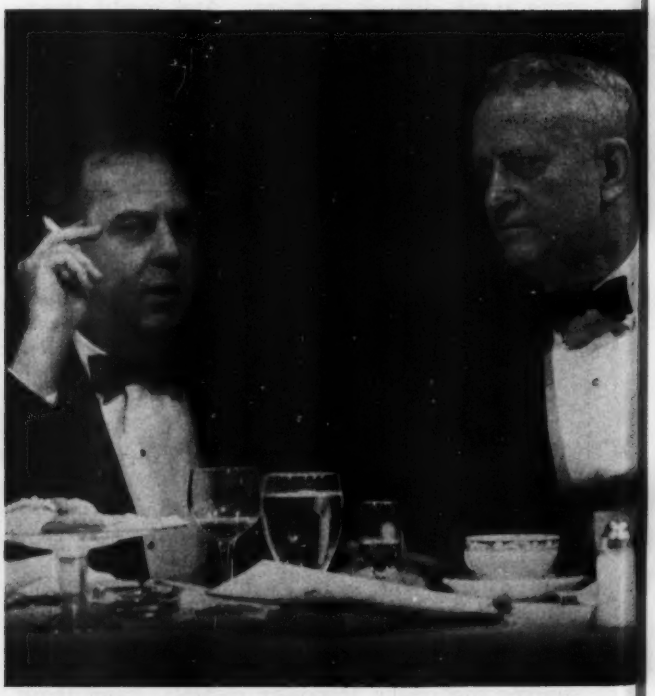
1961 ANNUAL BANQUET

The Principal Speaker, Admiral Burke, the President of ASNE, and the G Medalist.

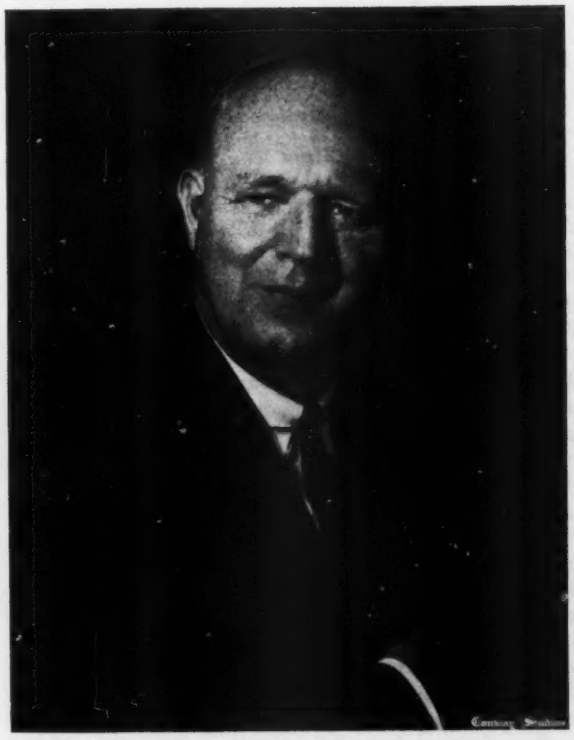
Below: Top—Admiral Burke with Admirals Thiele and Mumma.

Bottom—Admiral Burke, Admiral Stroop, Admiral Williams.

Mr. Newell and Admiral Burke.



REBUILDING THE AMERICAN MERCHANT MARINE DRY CARGO FLEET



ADMIRAL JOHN M. WILL, USN (RET.)

THE PRINCIPAL SPEAKER

ADMIRAL JOHN M. WILL, USN (RET)
PRESIDENT OF AMERICAN EXPORT LINES

Admiral John M. Will is President of American Export Lines, Inc., and Chairman of the Board of Directors. He is also a Director of American Merchant Marine Institute, the American Steamship Owners Protection and Indemnity Association, the Maritime Association of New York, the National Cargo Bureau, the New York Shipping Association and the West Side Association of Commerce. In addition, he is a member of the Classification Committee of the American Bureau of Shipping, and of the Board of Governors of the Whitehall Club.

Admiral Will joined American Export Lines on July 1, 1959, the day following his retirement after 40 years in the United States Navy.

While in the Service he was regarded as a most versatile Naval leader: a technical man with a master's degree in engineering, a World War II combat leader, a submarine warfare expert and an able personnel administrator. He became Commander Military Sea Transportation Service in July 1956.

During World War II, as a submarine squadron commander, his ships penetrated deep into enemy waters to inflict heavy damage to enemy shipping.

Admiral Will was born 15 September 1899 at Perth Amboy, New Jersey. He entered the U.S. Naval Academy, Annapolis, Maryland, on appointment from his native State, graduating 8 June 1923 with the rank of Ensign. His first assignment was on the battleship NEW YORK until January 1925. Following this, after a short destroyer assignment he reported to the submarine school, New London, Connecticut and served for the next 18 years until 2 July 1945 in the submarine service including a postgraduate course in Diesel Engineering at Annapolis followed by instruction at Pennsylvania State College, where he obtained his master of science degree in 1932.

From February 1935 to March 1937 he was Resident Inspector of Naval Material at Fairbanks-Morse Company, Beloit, Wisconsin. Here he supervised the development and construction of the first opposed piston-type submarine propulsion engines. In 1937 he assumed command of the submarine PORPOISE.

He received two awards of the Legion of Merit for

his record with the submarine force during World War II.

In November 1949 Captain Will became Commander MSTS Eastern Atlantic and Mediterranean. On 1 January 1951 he attained flag rank and in April reported as Commander Military Sea Transportation Service, Atlantic Area, and Naval Control of Shipping Officer, with headquarters at Brooklyn, New York.

In February 1955 he reported as Director of Personnel Policy, Office of the Assistant Secretary of Defense (Manpower Personnel and Reserve), Washington, D.C.

From July 1956 until his retirement on 30 June 1959 after 40 years of naval service, he commanded the Military Sea Transportation Service.

In August 1958 he was presented the American Legion Merchant Marine Achievement Trophy Award by the Secretary of Defense, cited for "his devoted and continuing service for the betterment of the American Merchant Marine and for promoting bettter understanding and confidence in relationships between the Government and the American Shipping Industry."

Address by
ADM. JOHN M. WILL, President
American Export Lines
to the
American Society of Naval Engineers
Washington, D.C., April 28, 1961

WHEN I WAS HONORED by the request to speak before this distinguished audience, I naturally searched for a subject that would be of interest to you and a source of pleasure to discuss.

The reconstruction program of our merchant marine, at least for dry cargo ships, fulfills much of this requirement. There is a great deal of justified pride and satisfaction, on our part, on the part of the designers, engineers and shipyards and, last but not least, on the part of the Government, for the results so far achieved. The program for further new construction promises more work for American yards and labor. It demonstrates the earnest desire to modernize our fleets and to keep the American flag flying on the seven seas.

This program is a tremendous undertaking, unequalled in peacetime. Various estimates have been made of its overall cost. The figure currently used by the Maritime Administration is $4 billion. Under present legislation, about half of this or $2 billion will be paid by the shipping lines. To meet this huge demand, it is estimated that fifty per cent of the operator's share, or about $1 billion, will be raised in "new money" through bonds, loans or equity. When completed, 300 dry cargo ships will have been built in a period of approximately 12 years. Since 1958, 61 dry cargo and cargo/passenger combination vessels have been ordered. Nine different shipyards have received contracts at a total cost of $655 million. Of these 61 vessels, twelve freighters and four combination ships have already been delivered.

These are all excellently designed, and faster than all our present dry cargo ships, except the 34 Mariners. Only five have a nominal speed of 17 knots; all the others are rated between 18 and 20 knots. They all have steam turbine propulsion plants with extremely conservative power margins. At least one extra knot of speed is available under most service conditions. All are big ships, with the smallest design having an overall length of 484 feet.

All these new vessels are equipped with the most modern cargo handling gear, mechanically or hydraulically operated hatch covers, and air-conditioning for passengers and crew.

Naturally, the building of these 300 ships will have considerable impact on domestic industries, since by the terms of our subsidy contract all must be built in American yards with American materials. It was recently estimated that the electrical industry will benefit from this program by supplying about $1 million worth of electrical equipment for each ship. This will include everything from generators and cargo winch motors to switchboards and public address systems. Then, too, there are radar and radio devices, electric steering gear systems, cargo hold humidity controls and many, many more items. In total, the electrical industry can count on $300 million of new business. We dare to hope that in spite of the extremely high cost of building, we will still be able to successfully meet foreign competition.

Few blessings are unmixed, however, and when we speak of the fleet replacement program in such glowing terms we are apt to overlook the tremendous financial burden which it implies for us, the shipping lines, and for the U. S. Government and the taxpayer.

After World War II, when America and its allies had lost most of their privately-owned merchant fleets, our government made available an endless number of war-built ships—some mediocre, some very good—at prices which were based on pre-war building costs. One million dollars was paid, on an average, for each C-class vessel. The mass-built Victories and Liberties went cheaper. These are the ships with which we, and many foreign lines, have been conducting our freight business ever since the ending of World War II.

By contrast, the first four of American Export's new ships cost us almost six and one-quarter million dollars each, after a construction subsidy of about the same amount. The second group of four will each cost about five and three-quarter million dollars and the third group will be four and three-quarter million dollars. The average of five and one-half million dollars per vessel is a staggering sum compared to the $1 million average cost of the ships beings replaced.

This means that depreciation and insurance will be five times as much on the new ships. In the immediate post-war years everybody clamored for fast write-offs. Now the trend is in the opposite direc-

tion in the hope of easing the burden of capital charges. The Merchant Marine Act of 1936 was changed recently so as to enable us to amortize the new ships over a twenty-five year period instead of the twenty required up to now.

As I mentioned before in general, the new ships are faster and larger. We hope to carry more cargo with fewer ships, provided increased port time does not absorb all the advantages of higher sea speeds. International freight rates may rise, but after all, this benefits the competing foreign lines as well as ourselves. The foreign operators may choose to build new and more efficient ships, but unlike ourselves they are not contractually bound to rebuild their fleets on a pre-set timetable. In the final analysis, freight rates depend on economic conditions and the supply of world tonnage.

Present day conditions are not too favorable for the profitable operation of our new large ships. However, world business shows a trend toward improving, and this heralds better cargo volume and rates. Most important, though, our American manufacturers, importer and exporters are beginning to respond to our "Ship American, Travel American" campaign. Their support is a necessity if American flag shipping is to continue to exist in spite of higher capital and operating costs.

Will the cost of new construction go down further? Remember, our new "Export" ships decreased in price from six and one-quarter million each for the first group to four and three-quarter million apiece for the third design. The swing of one and a half million, or 24 per cent per ship, over a period of three years was encouraging and hard-won. To some extent these cost reductions were due to a worldwide decrease in shipyard prices. However, they also resulted from our own vigorous campaign against overdesign and overbuilding. We conducted a complete, systematic review of the design in order to eliminate all possible extravagance, duplication and unnecessary embellishment. Of course, we kept the ship modern and retained all the sound technological innovations of recent years. We dared not overlook labor saving devices. We cannot expect to refine our design much further, and must face the sad fact that whereas our new vessels must compete on the sealanes, we are nonetheless not remaining competitive in the prices we pay for our ships. In some respects, we are "overbuying."

For example, the Japanese are building a series of so-called "S" type cargo liners, capable of 18 knots fully loaded. They sell for less than $4 million to any buyer, on quite favorable financing terms. While various finished details are austere by American standards, the ships are, nevertheless, excellent cargo carriers and are adequate for their job. Similarly, German yards have been turning out very good, fast ships mainly for Norwegian and Dutch owners, which sell for around three and three-quarter million dollars per ship.

By comparison, the average American ship, now building, will cost between $9 and $12 million, of which the Government absorbs up to 55 per cent via the construction subsidy. While this is a considerable help, the American shipping line will still be "overbuying" and he will not reach actual partiy with his foreign competitors. Two questions present themselves: First—what is it that makes American ships so different, so much more expensive? Second—is it possible to increase their efficiency so they will be competitive with foreign built ships in spite of their higher first cost?

To the first question I would answer that we buy more costly ships because of our American mania for the "best" in its most embracing sense; indeed, because our society is conditioned to a concept of "minimum" that far exceeds that of those in other parts of the world with whom we in international trade must compete.

The prospective owner is practically compelled to design a distinct, individualized vessel for his particular route and trade. We are forced to satisfy our crews and unions, so air-conditioning, semi-private or private rooms with adjacent toilets and shower, comfortable furniture, and ample recreation areas become a standard, not a luxury.

Further, we must run the gamut of approvals and embellishments put on by countless review agencies. The Public Health Service, the Coast Guard, the Classification Societies and the Maritime Administration all have differing requirements which tend to be additive rather than conflicting. It is not sufficient to satisfy any one of these; all of their requirements must be met. I might add that "safety" demands, in the sense of personal safety and operative dependability, have done more than any single thing to drive our ships toward complexity and higher first cost. Economic prudence just never wins when opposed by our American idea of supersafety, as voiced either by labor or government.

National Defense requirements add to the cost, at times unnecessarily, as does the Maritime Administration policy of seeking vessels of general usefulness regardless of the specialized trade. Many operators have been forced into building faster, larger vessels than they need to meet their commercial requirements. Structures and systems have been oversized and overcomplicated in anticipation of potential military need which may arise twenty years in the future or may never arise in the life of the ship. Elaborate wash-down systems are installed which have no commercial use whatever. The operator receives a token contribution toward the first cost of the structures and equipment. This seldom exceeds 3 per cent of the vessel's price, and no effort is made to compensate for the continuing costs of depreciation and insurance during the vessels' twenty-five year life. Nor is any effort made to compensate for the increased maintenance burden on the operator. He must maintain a power plant

15 per cent to 20 per cent larger than he would have bought were his commercial needs the only consideration. Not only boilers and turbines are oversized; we see proportionately larger auxiliary equipment, piping, electric services and fixtures, with greater repair costs. We must provide cargo gear larger than we need for our daily operation. This means heavier booms, bigger king posts, more complicated running gear. Special shock-proof materials are more expensive to buy, install, maintain and replace. In short, the subsidized operator bears considerable expense throughout the life of his ship which his competitors never have to face. I hope this gives some insight into the physical reason for our more expensive vessels.

My second question was as to the possibility of increasing the efficiency of our vessels so they will be competitive with foreign-built ships despite their higher first cost. We in the industry must necessarily rely upon the complete understanding and cooperation of the Marine Engineering profession to work with us to attain this goal.

We all acknowledge that since the Second World War, naval architecture and marine engineering have progressed substantially. New cargo handling gear has been developed, new container systems tried, hatches mechanized and navigation aids made more precise. We have seen the development from scotch boilers to high pressure, high temperature water tube devices, and, indeed, are anticipating the benefits to come from nuclear power generation. Reciprocating engines have given way before the modern compounded turbine with reliable reduction gears. The high power, supercharged, large piston diameter diesel engine is a technical reality and quite popular among the world's merchant marine. Developments in gas turbine and free piston engines are promising.

Yet, aside from the hydrofoil, which doesn't seem to lend itself to larger vessels, we have heard of few bold breakthroughs in the barriers limiting our hull design. In spite of model tanks and craftsmen throughout the maritime world, hull forms are much as they have been for centuries. True, we know more of the science of ship resistance, but we are still caught in the equation where power must be increased eightfold in order to double the speed, and vessel length must be greatly increased to accommodate small changes in speed. The geometry of traditional hull form and the phenomenon of wave-making resistance seem to rule us in an uncanny and insurmountable way. Maybe they are destined to be as inviolate as the law of gravity, yet even so basic a concept as gravitational attraction has seen radical development with our space age.

I don't think hydrofoils are the immediate answer for water transportation, nor do I feel that submarine forms can commercially overcome the problem of harbor depth restriction. But these inquiries are healthy trends and are to be encouraged. Maybe there is an intermediate step between the conventional hull, the Albacore submarine hull, and the hydrofoil. The University of Michigan is investigating a Japanese development—described as a "carefully designed bulbous underwater snout"—that may lead to decreasing vessel power requirements by 10 per cent to 25 per cent. The potential return on this kind of research is staggering. I also wonder if a planing hull cargo vessel is an outlandish thought when pondering advances in propulsive machinery. It may be that some salvation is to be found in changes in cargo handling concepts or terminal procedures, or in further mechanization of various shipboard functions. Even so, we should nonetheless exhaust all streams of inquiry into bettering our hull forms to obtain speeds at less power and therefore less fuel consumption.

The Maritime Administration is now beginning an extensive study into all parts of each phase of our commercial merchant marine. They are to be congratulated for the broad program they are implementing and they have the whole-hearted support of our industry. Here is a fine example of funds, manpower and brainpower aiding us in our task of better competing on the world's waters. It is gratifying that they are aware of the burdens we carry with our higher vessel costs, and that "gadgets for gadgeting's sake" is subverted to the reality of competitive economics.

The subsidized shipping companies and the government have an obvious interest in getting more efficient ships. All of the members of this Society share this interest, indeed, we will all benefit by improvements in American marine technology. Whether naval or commercial, domestic or transoceanic, all of these interests have so much in common that everyone will benefit from the advances made.

The joint goals of reducing first cost and competing effectively truly touch each of us. They are not restricted to the companies rebuilding their dry cargo fleets. The freighter company problems are merely symptoms. We must all be aware of the threat in these symptoms and lend our ingenuity, effort and influence to combat them. Remember that symptoms often precede serious illness. As individuals, companies and a nation, we stand to lose our status as a maritime power unless we demonstrate our ability to effectively compete.

COMMANDER THOMAS K. EWAN, USNR

AN AERODYNAMIC COMBUSTOR

THE AUTHOR

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THE SONIC BARRIER, for many years man's adversary in attaining higher speeds, now holds promise of becoming his ally to attain even higher speeds. The nature of the sonic barrier has not changed. Supersonic speed has opened vistas so that the sonic barrier can be used to serve rather than impede man's quest for higher speed. Once the strength of the sonic barrier offered a formidable wall to man's traveling beyond the speed of sound. Today the strength of the sonic barrier offers a means of building supersonic and hypersonic air breathing engines without moving parts and without internal metal parts to provide locomotion faster than the speed of sound.

The "aerodynamic combustor," a device using sonic air to replace metal parts, offers the possibility of an extremely economical propulsion plant for supersonic speeds (Figure 12). In principle this engine is simplicity itself; however, its refinement to a practical propulsion plant offers an interesting challenge. There are two major components of the aerodynamic engine. These are the diffuser and the combustor. The purpose of the diffuser is to convert the kinetic energy of the incoming air into the pressure energy and to receive the thrust produced by the expulsion of the heated gases. The combustion mechanism is composed of a combustion chamber, a fuel injector and sonic air forming flameholders. It is to be noted that for the aerodynamic combustor propulsion principle to operate it must be launched at a speed at least equal to the speed of sound or faster. It will be noted the fuel is injected along the walls of the combustor (Figure 12) and that this fuel is in turn picked up by tangential air and swirled inward to provide a hot central core. The fuel aids in the cooling of the walls. A fuel meter may be used to regulate the fuel delivered to the combustion chamber. This must be capable of compensating for changes in both flight altitude and velocity. It is at this point, with a stable flame and

essentially complete combustion occurring in the combustor, that the means is provided aerodynamically to maintain a stable flame in a gas stream of high velocity. The sonic wall creates regions where the velocity flow is sufficiently low to permit the maintaining of small flames. These in turn are a source for continuously lighting the main high speed stream. With the combustion chamber acting as a confining area, the aerodynamic combustor now provides for air-fuel mixing and for holding the flame front. In this device the sonic barrier performs the work formerly performed by metal parts.

The aerodynamic combustor, though simple in theory of operation, will require extensive research for development. There are technical problems where answers to basic fundamental questions have to be found. Among the more important questions involved in the development of this type engine are the following: Can an aerodynamic combustor be produced that will develop thrust over drag? Can it be constructed so that it will start reliably after being launched into the air at high speed? Can efficient combustion be maintained through a wide range of altitudes and wide air-fuel ratio changes associated with missile flight? Can such an engine's thrust be governed in flight and permit successful guidance? Can the aerodynamic sonic barrier perform all the functions previously relegated to metal? This is the challenge.

The basic principle of the aerodynamic combustor is to provide a mechanism which can receive injected fuel, mix it with large quantities of high speed air and promote burning within a chamber without internal metal parts and without moving parts. In this device the sonic wall provides for both the mixing of the air and fuel and holding of flame front in a manner that the chemical energy of the fuel can be released in the form of heat. The heat in turn increases the temperature of the gas stream and, hence, the actual velocity and exit momentum of the stream. The aerodynamic combustor is a rate of change device in which the device is propelled by the expulsion of the heated gases. It incorporates the basic principle of the ramjet, first patented in 1915 by a French engineer, Rene Lorin. The ramjet principle is the momentum principle in terms of the production of useful thrust. According to this principle, the thrust developed is equivalent to the difference of momentum between the outlet and inlet flows. The momentum change is further equivalent to the integral of the internal pressure forces taken in an axial direction. The thrust "pushes" against the sloping walls of the diffuser, the innerbody, and the exit nozzle providing forward motion. There is also an external pressure integral which is the aerodynamic drag. The difference in these is the useful or net thrust available to propel the object.

The ramjet, commonly referred to in guided missile terminology as the "flying stovepipe," cast aside the moving parts of other propulsion devices. It requires no moving parts except for fuel regulation and control. Further, it obtains the oxygen from the atmosphere through which it passes for the combustion process. The oxygen is burned in combination with other fuels. This offers a great advantage over rockets (which must carry their own oxygen). This greatly reduces space, weight and lifting requirements. Conversely stated, the air breather can be constructed smaller and lighter and carry a larger payload.

Today we stand on the threshold of another significant development possibility—the replacement of the metal flameholder of the ramjet with directional air at sonic velocity to perform the functions of metal components. Modern missile technology suggests that we learn to use the oceans of air surrounding the earth. While ballistic missile development gives cause to consider missile operation outside the earth's atmosphere, we need remember that as long as humans live on this planet surrounded by layers of atmosphere, we need to use and to learn how to improve the use of air to serve mankind. All humanity and plant life, our automobiles, airplanes, motor boats and motor bikes employ the air around us. We need to learn to use it more efficiently, to use it as an ally. While the use of sonic air to replace metal parts represents a sharp departure from the unending search for improved metals to meet ever increasing thermal and structural problems, it is not surprising that man should seek to replace metal with sonic air in devices that fly. Already other fields of endeavor seek to use air to better meet the needs of modern technology. For example, work is going forward in the field of gas-lubricated bearings needed in applications where conventional lubricants cannot meet the need. The possible uses of air extend across a wide range of applications.

To better understand the possibilities of the aerodynamic engine we need to first review our understanding of the phenomena experienced when objects move through air at speeds from less than that of sound to speeds faster than that of sound in the medium being considered. Many of the terms used to describe modern missile performance have dual meanings. An example of this is found in the words sonic, subsonic, supersonic and hypersonic. In one meaning sonic applies to sound phenomena and the auditory ranges of the human ear. In a second meaning it concerns the phenomena resulting when a fluid flows or when an object moves through a fluid. To understand the operation of the aerodynamic combustor we need concern ourselves with the latter meaning as generally considered in the field of physics, namely a form of pressure gradient or variation moving through some material medium. This difference is generally referred to as a wave. The elasticity of the medium determines the speed with which the wave moves through it. In the case of air where the pressure changes are small and

rapid, the square of the speed of sound varies directly as the ratio of pressure to density. Temperature affects the speed of sound and similar pressure waves in air at the rate of approximately two feet per second for each degree Centigrade change. For example, the speed of sound in 86°F air is approximately 777 miles per hour or 1140 feet per second. The speed of sound in 95°F air is approximately 784 miles per hour or 1150 feet per second. Now, considering the case of cooler air we find that the speed of sound in 77°F air is about 1130 feet per second or approximately 770 miles per hour. These figures consider only normal conditions where pressure conditions are quite small and do not consider high intensity pressure variations associated with explosions. If we think back to our childhood, we will recall our wonderment of the vibration of the walls and windows of a building from the beautiful notes of a pipe organ. We recall also our wonderment of why the windows vibrated at the sound of the train whistle or why airplanes caused buildings to shudder. We have now come to understand this—simply that sound is a form of pressure variation which moves through some material medium.

If an object moves through the air with a speed less than the pressure wave speed, we have speed that is subsonic, the pressure waves precede the object (Figure 1). In order to understand this more clearly let us assume that a rock is hurled through the air; now let us examine Figure 1. We will note that the rock moving through the air at a speed less than that of sound is preceded by the sound waves it has generated. This rock traveling at a subsonic speed will not overtake the sound waves. Now let us take the same rock and have it expelled from a gun barrel at the speed of sound; here the speed of the rock is equal to the speed of the pressure waves

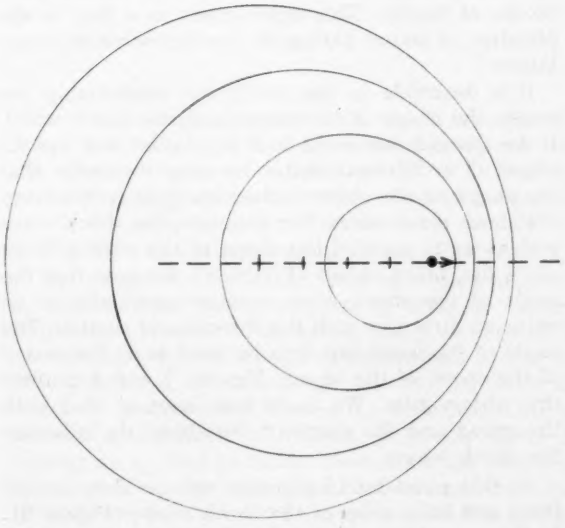

Figure 1

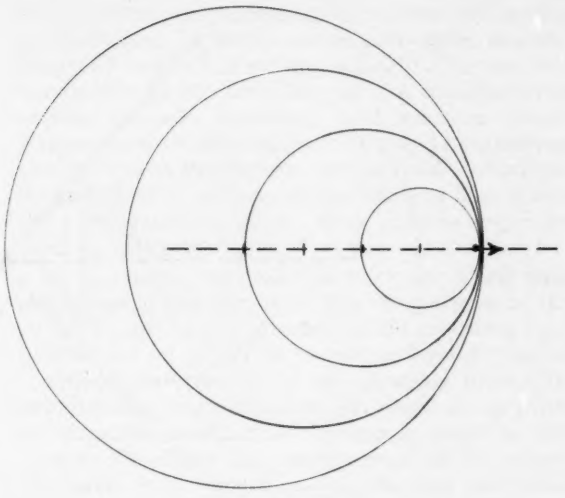

Figure 2

(sonic speed). These pressure waves converge to form a wall in front of our rock. Now let us examine Figure 2. Here we see what is commonly known as the sonic barrier where all the waves ahead of the rock have combined into a single wall or barrier. This shock wave is a very strong force made up of the combination of the smaller forces which have converged. From this condition we obtain requirements necessary to replace metal parts with air and for the development of the "aerodynamic combustor."

Over the past decade men have sought means of quickly passing through the sonic barrier into the supersonic speed range. Considerable efforts have been expended to overcome this sonic barrier and to limit its effects. Figure 2 makes it easy to understand why propellers need to be discarded in reaching supersonic regions of flight. It further exhibits why it is necessary to go quickly from subsonic to supersonic to break through the wall or barrier which is as strong as metal at sonic speed. Man has tried to limit the effects of the sonic barrier and he has neglected to use this barrier as an ally. Ever increasing technological problems now dictate that this barrier be transformed from an enemy into an ally. It is here that a new door is opened to a new type of propulsion device to move objects faster, more cheaply, more quickly.

Before discussing further the propulsion device available by putting the sonic barrier to work, let us examine a few more examples of sound in the sonic, subsonic and supersonic regions. First let us understand the condition existing aerodynamically as described in Figure 3 where a bullet is fired at a speed greater than the speed of sound, that is, supersonic or a speed greater than the pressure wave speed. While this situation is more difficult to show in diagram, it actually presents a less difficult situa-

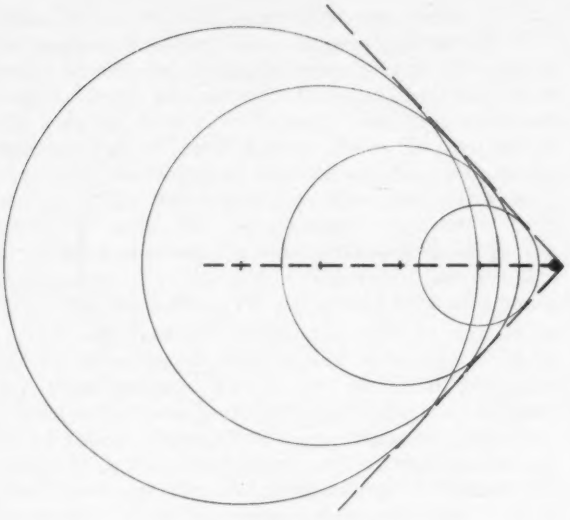

Figure 3

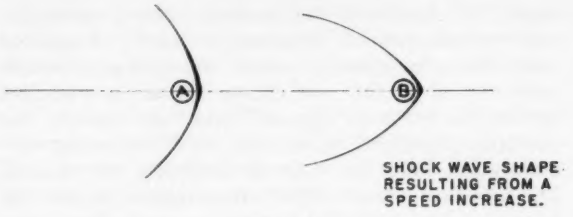

Figure 4

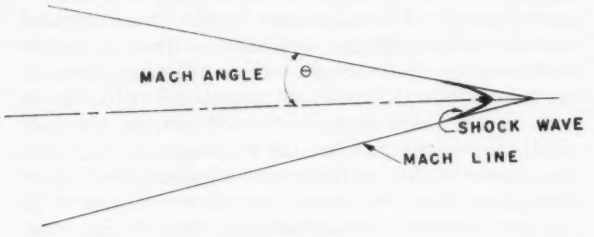

Figure 5

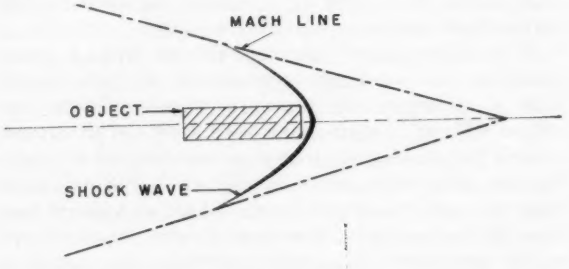

Figure 6

tion with which to deal. In Figure 3 we note the bullet preceding the shock waves where a conical region of compression precedes its path. It will be noted here that the pressure waves converge ahead of the bullet and along the sides of the bullet. This results in the bullet's having, in effect, a conical region of compression surrounding its path. These do not retain their identity as shown for purposes of illustration, but merge into a single compressed wave. The compression is the greatest immediately in front of the bullet. Shock waves are the titles given to the disturbances shown in Figures 1, 2, and 3. It is important to recognize that the shape and the speed of the object determine the angle between the object and the shock wave. Using our rocks and bullet as the objects we have the following conditions relative to speed relationships and shock waves (Figure 4). We will deal with the shape relationship of the object and the shock wave subsequently. It is necessary to complete our understanding of this problem to define the term "Mach lines." These are imaginary straight lines corresponding in direction to the shock waves set up by the motion of the object. These are straight and meet at a point as indicated in Figure 5. The speed of an object in air is commonly referred to as the Mach number which is obtained by dividing the speed of the object by the local speed of sound. Thus, at sea level in air at the standard U. S. atmosphere, a body moving at Mach Number 1 would have a velocity of approximately 1116.2 feet per second. We can now discern that as an object moves through air at speeds greater than that of sound it is preceded by a layer of highly compressed air. The compression decreases as the distance from the path increases. When the object is moving slower than the speed of sound greater changes are permitted to take place in the air stream. However, at supersonic speeds the particles of the air stream are subjected to sudden and considerable changes in the motion. Here the shock waves bunch the air into almost solid blocks of matter. This again gives us a key to application of sound barrier to the aerodynamic combustor.

It is desirable to also study the relationship between the shape of the object and the shock wave. If we discard our rocks and our bullet and use an object of a different shape, we may recognize that the shape of the object influences greatly the form the shock wave takes. For example, the shock wave endeavors to parallel the shape of the object. If we use a flat, blunt object (Figure 6), we note that the angle of the shock wave changes gradually in an outward direction with the direction of motion. The angle of the wave can thus be used as an indication of the speed of the object. Figures 7 and 8 confirm this observation. We have now learned that both the speed and the shape of the object do influence the shock waves.

At this point let us consider the air flow on the front and back sides of the shock wave (Figure 9). In the case of normal shock on the down stream side of the shock wave the movement will be subsonic.

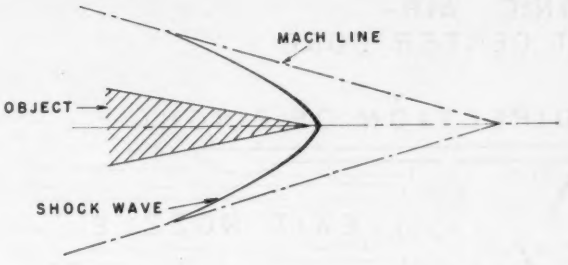

Figure 7

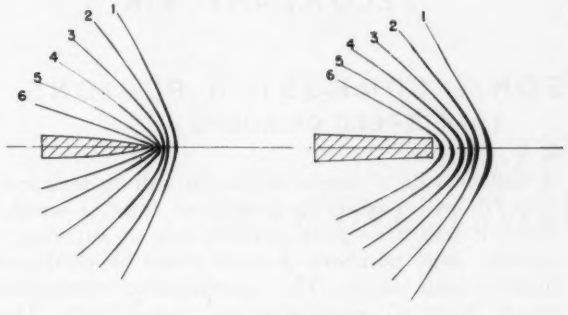

Figure 8

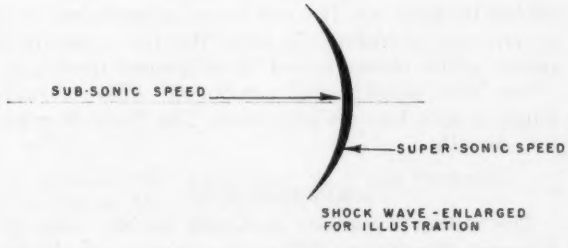

Figure 9

However, it is possible, when the shock wave is oblique (not normal), to have supersonic speeds on the down stream side of the shock wave. It is to be noted that the direction of the air flow is not parallel to the shock wave, but more nearly parallel to the surface of the moving object.

Before proceeding further it is important to briefly review fluid flow principles. In order to understand the operation of an aerodynamic combustor it is necessary to understand flows through a tube of changing area. Among other things, the flow of fluids is governed by Bernoulli's Equation. This is merely a statement of the law of conservation of energy as applied to fluids. Here we must consider the case of energy as applied to fluids and the case of both compressible and incompressible fluids. For incompressible fluids the relationship is quite simple. Using air, which is a compressible fluid, as does the aerodynamic combustor, a complex relationship is established by the pressure and speed changes. Figures 10 and 11 show that entirely different relationships exist for flows in a tube of changing cross section at sonic, supersonic and subsonic speeds. Expressed in its simplest form it may be stated that at slow speeds the viscosity of the fluid is more important than its compressibility while at high speeds the compressibility of the fluid is more important than its viscosity.

At this point it is desirable to review a few basic aerodynamic fundamentals. For the purpose of this study we are most interested in the retarding force exerted on an object as it moves through the air commonly referred to as aerodynamic drag. This aerodynamic drag influences the shock wave which accompanies an object at supersonic speed as well as does the shape and configuration of the object. The drag on an object moving through air results from surface friction, impact forces, and partial vacua. A plane surface oriented parallel to the flow of the medium results only in surface friction. However, if we turn the surface of an object at an angle with the direction of flow, the impact of the stream on the upstream surface must be considered as well as the effect of a partial vacuum on the rear surface. It is obvious that for other than plane surfaces the situation becomes more complex with friction, impact and vacuum contributing in various degrees. The roughness, the angle of attack into the stream, the velocity and density of the stream determine the amount of drag for a plane surface. However, for other than a plane surface the drag also depends upon the shape. It is to be noted here again that subsonic and supersonic flows exert different relationships. The surfaces which give minimum drag at subsonic speed are not the same as those which

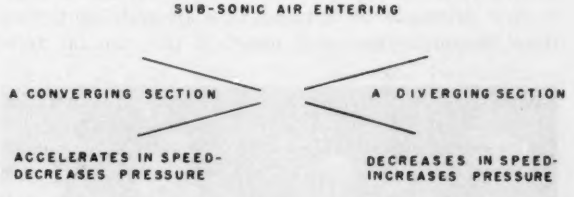

Figure 10

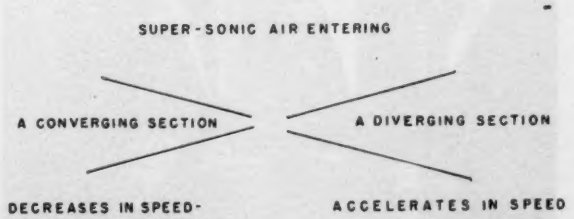

Figure 11

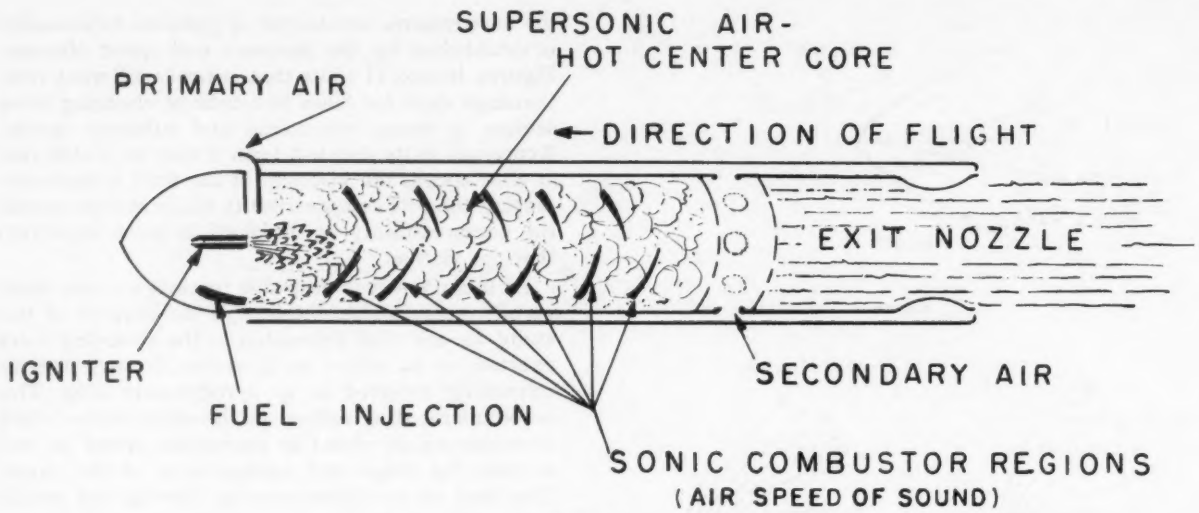

Figure 12

give minimum drag at supersonic speeds. This accounts for the vast difference in design and shape of objects designed for subsonic and supersonic flight.

We may now conclude that the sonic barrier offers the possibility of being "shaped" just as we shape metal parts. We also may conclude that it offers the strength to provide for air-fuel mixing, for providing flame fronts and flame stabilization in high speed air streams. The onrushing technology in higher speeds and higher temperatures brings us to the upper limit of thermal and structural capability of metal components in many applications. While the development of an aerodynamic combustor for propulsion devices presents a formidable task it also offers a bold approach to replace the functions of metal parts with sonic air in propulsion devices.

Today the basic merits of the aerodynamic combustor principle as applied to a propulsion device need demonstration and proof. If this can be done it will provide a simple engine; it will be inexpensive; it will possess an excellent thust-to-weight ratio; it will have peak performance at supersonic speeds; large numbers of units could be produced quickly and easily. The aerodynamic combustor would have no rotating or reciprocal parts. The turbine and compressor of the turbo jet would give way to a simple duct using supersonic compression. The internal metal parts of the ramjet would be replaced by sonic air. It could be mass produced with a minimum of tooling. To make this into a practical power plant research and development need continue. The "aerodynamic combustor" offers a challenge—convert an old adversary, The Sonic Barrier, into an ally.

ACKNOWLEDGMENT

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Official U. S. Coast Guard Photo

At the Annual ASNE Banquet.
Admiral Burke, Admiral Cowart, Captain Smith, Admiral Cronin, Admiral Stroop.

"THE SHIPBUILDER AND MARINE ENGINE BUILDER"

TECHNICAL PROGRESS IN MARINE ENGINEERING DURING 1960

ACKNOWLEDGMENT

This staff article was published in the January 1961 edition of "The Shipbuilder and Marine Engine Builder."

FREE-PISTON MACHINERY AND GAS TURBINES

Free-piston Machinery—General

A COMPARISON IS MADE of the spark-ignition, compression-ignition and gas turbine and free-piston engines by Mr. A. Braun in the *Engineering Journal* (Montreal) of July, 1960. The basis is the usual simple general expression for the thermal efficiency in terms of the compression ratio and the isentropic exponent. For the spark-ignition engine, a compression ratio of 10:1 is close to the practical and economic limit; in compression-ignition engines, mechanical and structural considerations limit the compression ratio to 22:1. The gas turbine compression ratio is controlled by metallurgical considerations imposed by the temperature in the combustion chamber and turbine; at present the limit is 7:1.

In the free-piston engine, the gasifier compression ratio is not limited in the same way and extremely high compression ratios are used; present volumetric compression ratios are between 40 and 60:1 and 80:1 is expected to be reached after some further development. A table is given showing the actual efficiencies appropriate to the compression ratios mentioned. That for a free-piston engine is quoted as 38 per cent and 41 per cent, respectively, for compression ratios of 40 and 80:1 and is compared with 36 per cent for a compression-ignition engine with 22:1 compression ratio.

A summary of the advantages of free-piston machinery is given under the following headings:—simplicity, compactness and flexibility of installation and of operation. The possibility of overload, without time limit, by means of afterburning has not yet been widely developed. As an engine type they are in a comparatively early stage of development and further improvements can be looked for in respect of power/weight ratio and specific fuel consumption as a result of increased compression ratio.

Central Annulus Design

At the 1960 meeting of the Association Technique Maritime et Aéronautique, M. A. Moiroux described the problems encountered in the design of the central annulus of the combustion chamber of the GS-34 free-piston gas generator (the title of the paper is "An Experimental Study for an Annular

Combustion Chamber for a Highly-supercharged Two-stroke Engine—The Base of a Free-piston Gas Generator"). The author points out that since no appreciable cooling of the scavenge air occurs after its compression (to approximately 57 psi), the average cycle temperature is high (approximately 2,010 deg F). The violent turbulence during scavenging considerably aids combustion but at the same time increases rate of heat transfer to the wall so that the temperature of the internal face of the combustion annulus is about 930 deg F. The resulting thermal stresses can be considered to be constant, superimposed on which are the cyclically varying stresses due to gas pressure. Also superimposed are the stresses due to method of attachment of annulus to the skirts and the local stresses due to design details such as the bossings and screw threads for the six injectors.

The first phase of the development was concerned with the choice of a suitable material. A heat treated steel which stood up to the gas side conditions had to be rejected because of a tendency to pit on the waterside; these pits formed local stress raisers and were often associated with fatigue failures. The use of a stainless steel of high corrosion resistance surmounted this problem and was followed by a redesign of the annulus (*a*) to reduce stress concentrations and (*b*) to eliminate the high thermal inertia of the flanges. The new design had a thinner wall and was without flanges, the end joints being made by separate two-piece connecting rings.

Finally, stress measurements were made and the principal stress concentrations were reduced by modification to the injector bossings. The results are presented in graphical form.

G.T.S. Rembrandt

During the summer the G.T.S. *Rembrandt* successfully completed her sea trials. Of 12,940 tons deadweight and 492 ft overall length, the *Rembrandt* is the largest cargo ship with free-piston machinery at present, and was designed from the outset for this type of propelling unit. The maximum continuous output is 4,000 S.H.P. at 110 rpm and is supplied by five GS-34 gasifiers (one of which is a standby) and a single exhaust turbine. The main machinery weighs 83.1 tons, representing a saving of about 200 tons compared with a conventional installation, and at the same time, compactness of the installation has allowed six frame spaces to be saved.

The gasifiers, manufactured by Smith's Dock Co., Ltd., South Bank, have been designed with recirculation so that turbine requirements can be matched over the whole power range, and when idling they develop only 20 H.P. each. The turbine has six reaction stages giving the performance shown in Table I.

The double-reduction gearing is of the locked-train type; the high speed pinion meshes with two single-helical gears, the thrust of which opposes that of the turbine. If the load is excessive, an overdrive claw coupling transmits the drive direct to the pinion, instead of through the quill drive. A KaMeWa controllable-pitch propeller is fitted and specially designed Chadburn telegraphs relate pitch requirements for different speeds to the fuel rack setting on the gasifiers. On trials in the ballast condition, 3,870 S.H.P. was developed at 0.428 lb per S.H.P. hr. on Diesel fuel, giving a speed of 14.6 knots.

TABLE I

	1 Hour Overload	Maximum, Continuous	
No. of gasifiers in use	4	4	3
Delivery pressure, lb per sq. in.	46.7	43.1	26.3
Delivery temperature, deg. F.	900	864	689
Total mass flow, lb per second	34.7	33.0	24.3
Output at turbine coupling, H.P.	4,600	4,110	2,000
Turbine rpm	7,050	6,800	5,350

G.T.S. Geestland

The G.T.S. *Geestland* is the first vessel built in the Netherlands to be powered by free-piston machinery. She is intended for service between the United Kingdom and the West Indies, and is 326 ft length overall and of 15.4 knots service speed. The unidirectional turbine is nominally rated at 4,000 H.P. at 5,500 rpm and the epicyclic reduction gear gives a reduction ratio of about 17:1 to the Werkspoor reversible controllable-pitch propeller.

Four GS-34 gasifiers manufactured by Messrs. Werkspoor, Ltd., supply the turbine with gas at 840 deg F when running on Diesel fuel; the temperature is expected to be 20 to 25 deg F higher when residual fuel is used. Air for the gasifiers is drawn from a compartment at the top of the funnel and passes down through two trunks, each of which supplies two gasifiers. The trunks incorporate a number of venturi pipes and an air tank below each gasifier further smooths out pulsations. On trials, 3,350 S.H.P. was developed at a fuel consumption rate of 0.42 lb per S.H.P. hr., giving a mean speed of 17.8 knots with a propeller rpm of 325.

Gas Turbines—The Ash Problem

In a paper read recently at the Second Liquid Fuel Conference—"Liquid Fuel and the Gas Turbine; a Ten Year Review"—the author, Mr. R. F. Darling, indicates that the worst problem facing designers is that of corrosion and fouling of the turbine by ash particles when burning residual fuels. The troublesome constituents are vanadium and sodium which reach the turbine as complex compounds of oxygen and sulphur. In most cases, the ash softens at about 1,200 deg F and readily adheres to blade faces, choking the passages and in-

creasing the rate of metal oxidation—the fouling aspect is predominant below 1,200 deg F and the corrosion aspect above. This temperature is also the lowest limit for any attempt at efficient working, but as yet no known blade material or coating is immune to fuel-ash corrosion at temperatures much above 1,200 deg F.

The difficulties met with in the endeavor to develop ceramic blading are very clearly set out in a paper entitled "General Development in Ceramics for Marine Engineering," by Mr. F. H. Aldred and Mr. M. W. Hinchcliffe (Transactions of the Institute of Marine Engineers, November, 1960). It is pointed out that at the present time there are two special ceramics of the non-oxide type (silicon carbide and silicon nitride) which come near to fulfilling the requirements for stator blades in a high temperature gas turbine and which might, with fuller development, be applied in practice. However, there appears to be nothing of this nature in sight for rotor blades, and much work has been done in an attempt to modify the ash properties of the fuel.

It is known that under favorable circumstances fuel droplets are not burnt to ash particles but to particles of carbon and ash combined, which remain hard and dry at turbine inlet temperatures in excess of 1,200 deg F and which pass through the turbine without initiating corrosion or choking. Practical application must await development of a precise and selective means of combustion control.

Modification of the ash properties by various types of additives has been widely attempted and in particular, it is found that oxides of magnesium, zinc and aluminum have good corrosion inhibition properties up to about 1,500 deg F, but, fortunately, increased proneness to fouling occurs. Various methods for mixing the additives and for eliminating sodium salts have been developed, but no additive has yet been found which reduces both fouling and corrosion to acceptable limits. Thus attention has been recently concentrated on methods for removing blade deposits, and as rate of blockage may be high, the cleaning medium must be able to stand up to exposure to combustion gases as it might have to be injected into the turbine inlet.

As yet no final solution to the ash problem has emerged.

G.T.S. John Sergeant

In March, 1960, a paper was read before the Gas Turbine Power and Hydraulic Conference of the American Society of Mechanical Engineers giving a "Report on 9,000 hours Operation of Marine Propulsion Gas Turbine in the *John Sergeant*." The 9,000 hours represents three years commercial operation of the vessel, and comprise fourteen round voyages, principally across the North Atlantic Ocean, under all kinds of sea and weather conditions (see Table II).

TABLE II

Total distance covered, nautical miles	128,346
Number of hours gas turbine operation	9,270
Estimated number of turbine starts, over	1,000
Highest average S.H.P. for transatlantic crossing	7,260
Lowest average S.H.P. for transatlantic crossing	5,021
Availability of turbine, per cent	99.7
All purpose fuel rate, lb per S.H.P. hour	0.522
Lubricating oil consumption, gallons per day.	0.1

The few unscheduled stoppages were caused either by faults in accessories or by some slight malfunctioning of the control system. The incidents occurring at sea were:

(*a*) Failure of atomizing air compressor caused by dirt-scored bearings (4½ hours).

(*b*) Faulty exhaust temperature detector tripped the turbine (five minutes).

(*c*) An electrical short circuit in wiring to the motor-operated fuel-oil transfer valve actuated this valve thereby tripping the turbine (2½ hours).

(*d*) Turbine tripped while increasing power, owing to the plugging of temperature detectors by fuel-oil corrosion inhibitor in the ash (14 hours).

In addition the self-synchronizing clutch of the steam starting turbine was damaged during a start-up by re-engagement under abnormal conditions. Most of these incidents were followed by modifications and are unlikely to recur.

The maneuverability of the vessel was excellent, bridge control of the machinery being used only during trials, since it was found that fuel lever trimming was necessary to compensate regenerator lag. The fuel washing and additive systems have given little trouble but have required careful and continuous attendance. Providing that sufficient corrosion inhibitor is added, the turbine can burn any fuel which can be properly desalted. The paper gives details of several residual type fuels which have been successfully treated. The compressor and turbines were regularly cleaned by water washing after each long sea voyage, and it was found that design efficiency was restored.

Two men per watch have been employed, but it is considered that an improved and fully automatic fuel treatment system would permit one-man watches, and, if the vessel were supplied with pre-washed and pre-treated oil, no watch keepers would be necessary.

The machinery was opened up and examined in the autumn of 1959. The compressor blading showed slight signs of erosion on the forward face with dents on a few leading edges. The combustion liners and caps were in excellent condition. The partitions of the first stage turbine nozzle ring showed some cracking had occurred at the trailing edges; maximum number of cracks in any one partition being three and the maximum crack length was 0.375 in.

Micrographic examination indicated slight intergranular penetration in this region (operating temperature 1,400 to 1,500 deg F) but all these parts were considered suitable for further use. All rotor blades were free from cracks or physical damage. The results of the inspection were considered to be very satisfactory, and no repairs or replacements were necessary in the critical hot regions of the plants, although various modifications and improvements to ancillary plant are suggested for future installations.

DIESEL MACHINERY

High-speed Diesel Engines

In the past, geared Diesel engines have not made much headway, but interest in such prime movers is reviving somewhat. A twin-geared Diesel installation offers an owner the possibility of maintaining full efficiency at half power (or approximately three-quarters of full speed), while a four engine per shaft installation allows optimum efficiency to be maintained to one-quarter full power. Many ships are now required to operate at reduced speed for long voyages as well as on short passages and while coasting, and the foregoing noted attraction of multiple geared Diesels has greater weight.

Daimler-Benz

In the James Clayton Lecture given to the Institution of Mechanical Engineers (1960) entitled "The High-speed Heavy-duty Diesel Engine—Its Development and Application," the author, Mr. E. Schmidt, comments on the performance of the Daimler-Benz high-speed Diesels which were installed in the two electrically-driven motor vessels *Tinnum* and *Archsum* and compares the weights of different types of machinery installed in other identical vessels (see Table III).

TABLE III

Power Plant	Weight of Power Plant Shafting & Propeller, Tons	Weight of Auxiliary Aggreg., Tons	Total Weight, Tons	Relative Weight Per Cent
Direct drive Diesel engine; 3,600 H.P.; 125 rpm	312	36	348	337
Two medium-speed engines with reduction gears; 3,600 H.P., 300 rpm	170	36	206	200
Five Diesel generator sets, electric motors and reduction gearing output of 4,400 H.P., 1,300 rpm	92	11	103	100

In addition to this weight saving, the high-speed generator sets could be installed right aft, giving extra cargo-carrying capacity of 15,000 cu. ft., bale, or 26,000 cu. ft., grain. Because of this saving in space, the high-speed Diesel installation is able to overcome its poorer overall efficiency and shows to advantage when based on fuel consumption per nautical mile per ton. With identical cruising speeds of 12.6 knots for identical annual distances of 60,000 nautical miles, the fuel consumption is 0.26 ozs. per nautical mile per ton for the high-speed Diesel-electric installation, compared with 0.3 ozs. for the directly-coupled Diesel installation.

Periods between engine overhaul have been extended from 5,000 hours to between 10,000 and 14,000 hours. Records from four engines with between 10,600 and 14,400 hours operation revealed the following wear:

Increase of crankshaft clearances	0.0028 to 0.0004 in.
Wear at piston top	0.0059 to 0.0118 in.
Wear at piston skirt	0.0012 to 0.0020 in.
Wear at top of cylinder	0.0028 in. max.
Wear at mid-stroke	0.0016 in. max.

For a cylinder diameter of 175 mm the author states that piston clearances may increase up to 0.0146 in. for top dead center and 0.0031 in. at mid stroke. It is stated that these Daimler-Benz engines burn residual fuels.

Mirrlees Monarch

During the year, a new British engine, the Mirrlees Monarch, was installed in the Hull trawler *Westella*. A 4SCSA turbo-charged engine, it is rated as installed at a b.m.e.p. of 138 psi at 225 rpm, developing 300 S.H.P. per cylinder. It is, however, also offered at a b.m.e.p. of 150 psi at 300 rpm at which rating it will develop 430 S.H.P. per cylinder. It is understood that design is also proceeding on a Vee-type version with a shorter stroke, which can probably be even more highly rated. Thus there is the prospect of a compact 16-cylinder engine of this type delivering as much power as some of the advanced American four-stroke designs which have created so much interest. The final design is expected to develop a unit, so that two Vee-16 engines (at 375 rpm) with conventional electro-magnetic or hydraulic couplings and twin-pinion reduction gears will provide the compact power unit on a single screw which many owners are seeking—at an attractive low installed weight. The *Mirrlees Monarch* is, of course, a heavy fuel burner and recent developments in lubricating-oil additives and cylinder lubricants should be able to take care of possible sulphur contamination in the crankcase of a trunk-piston engine of this size.

Two-speed Gearboxes

Two-speed gearboxes have been introduced, one on the tug *Sir William Luce* and the other on the

trawler *Lorwood*. In the tug, the machinery consists of two Ruston 7VEBXM turbo-charged Diesel engines each developing 630 S.H.P. at 500 rpm and arranged side by side. They are coupled through Fluidrive S.C.D. scoop-controlled hydraulic couplings to a Hindmarch-MWD twin-input, single-output, two-speed gearbox. The trawler is powered by a Lister-Blackstone-ERS8MGR turbo-charged Diesel engine developing 660 S.H.P. at 750 rpm to a Hindmarch-MWD single-input, single-output two-speed gearbox. The ratios are:

	Ahead Running		Astern Running
Sir William Luce	3.49:1	2.72:1	3.52:1
Lorwood	3.49:1	3.02:1	3.02:1

The input shafts carry three pinions, one for each ahead speed and for the astern working. The ahead pinions are in constant mesh with wheels containing the Hindmarch-MWD oil-operated clutch and these wheels are mounted on shafts which also carry the astern wheels and clutches, these latter wheels being driven through idlers from the input astern pinion. The final pinions are in constant mesh with the final wheel on the output shaft. There are two controls, one selects neutral, ahead or astern; the other selects the ahead ratio. Such gearboxes carry their own hydraulic and lubricating-oil pump, filter, cooler and regulating valve; they are stated to be compact and of relatively low cost.

Directly-coupled Diesel Engine—New Doxford Engines

Messrs. William Doxford & Sons (Engineers), Ltd., Sunderland, are producing two new opposed-piston two-stroke cycle turbo-charged engines, one of 560 mm bore and the other of 850 mm bore to the same basic design as their 670 mm bore turbo-charged engine which made its appearance in 1959. Each of the new engines will be built with four, five and six cylinders. Some of the particulars are given in Table IV.

The 560 mm bore engine has been introduced primarily for shallow-draft fruit carriers and for coastal ships having a suitable speed/length ratio.

TABLE IV

	850 mm Bore	560 mm Bore
Upper piston stroke, mm ..	830	630
Lower piston stroke, mm ..	1,670	1,120
Maximum rating, b.m.e.p.	119	130—118
rpm	115	120—150
S.H.P.	19,800 (6 cylinders)	
Continuous service rating, S.H.P.	18,000 (6 cylinders)	6,990 (6 cylinders)
Overall dimensions—		
Length	40 ft. 0 in.	41 ft. 0 in.
Breadth	14 ft. 6 in.	10 ft. 6 in.
Height	37 ft. 0 in.	26 ft. 0 in.
Weight, tons	440	227

3,000 S.H.P. Per Cylinder

It is reported that the new 900 mm bore single-acting two-stroke cycle turbo-charged Diesel engine developed by Fiat Grandi Motori, of Turin, has been run on the testbed at very high overload, developing a b.m.e.p. of 157 psi at 123 rpm, thus delivering 3,057 S.H.P. per cylinder. At present it is only being offered at a maximum continuous rating of 2,100 S.H.P. per cylinder at 122 rpm (b.m.e.p. 109 psi). However, as soon as practical experience under sea-going conditions has been acquired, the maximum continuous service rating is likely to be raised towards 2,500 S.H.P. per cylinder, so that 30,000 S.H.P. per shaft might become possible for a 12-cylinder engine.

New Götaverken Engines

A/B. Götaverken, of Gothenburg, have completed shop trials and are installing a 10-cylinder engine of 850 mm bore by 1,700 mm stroke with service b.m.e.p. of 106 psi which will develop 16,196 S.H.P. The engine is designed for a b.m.e.p. of 142 psi, and it is intended to operate at this increased rating after sea-going experience has been obtained at the lower rating. The power of this engine will then be increased to 21,200 S.H.P.

Exhaust Energy

In a paper presented to the Institution of Mechanical Engineers entitled "Influence of Exhaust Belt Design on the Discharge Process in Two-stroke Engines," the author, Mr. R. S. Benson, extends his previous investigations to practical conditions. The "belt" theory and the "enlargement" theory are explained and commented on and an analysis is given of the gas-exchange process. Experimental investigations were made on ten belt configurations, pressures being measured in the cylinder, belt and pipes; the results are quoted in detail. It was found that the pressure was not uniform within the belt. An increase in belt size reduced the restrictive effects, shortened the blowdown time and increased the pulse amplitude in the exhaust pipe. An optimum belt size was found, beyond which no further improvement was obtained unless the belt profile was altered. The optimum can be achieved within the normal engine dimensions. Design data for exhaust ports and belts, based on these investigations are given.

To estimate directly the exhaust gas energy available for turbo-charging a Diesel engine with a pulse system it is necessary to know the instantaneous variations of temperature, flow rate and pressure of the exhaust gases and there are great practical difficulties of doing this. These difficulties have been side stepped by means of an ingenious device mentioned by the authors, Mr. F. Nagao, Mr. Y. Shimanoto and Mr. H. Obayashi, in a paper entitled, "A Method of Measuring the Exhaust-gas Energy Available for Turbo-charging a Diesel Engine"

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(Bulletin of the Japanese Society of Mechanical Engineers, November, 1959). Part of the exhaust gas is ejected into the atmosphere through a nozzle similar to that of the proposed turbine. The momentum of the gas is measured as a thrust on a cage (which is described) and the flow rate is measured by means of an orifice. The mean ejecting velocity is then estimated in terms of its mean momentum and flow rate. The theory of the method is discussed and an example of its application is given, with typical results presented in graphical form.

Crankshaft Investigation

A few years ago a number of crankshaft failures in Doxford 750 mm engines caused considerable anxiety to owners and engine-builders and a valuable paper to the Institute of Marine Engineers (Vol. 72, No. 7) in April gives an account of the investigations undertaken to trace the causes of the trouble and to cure it—the title, "Some Crankshaft Failures: Investigations, Causes and Remedies," by Mr. R. Atkinson and Mr. P. Jackson. The engine, designed in 1949, is in general a scaled-up version of the earlier 600 mm and 700 mm engines of the normal Doxford type. Most of the failures originated in the fillets of Nos. 3 and 4 side crankpins in 6-cylinder sets, the crankshaft for which are in two pieces coupled together between Nos. 3 and 4 by means of a particular type of flexible coupling.

It transpires that torsional vibration was not a major cause of these failures. Misalignment was present in about one-third of the cases investigated and was shown to have considerable influence on crankshaft stresses; bedplate deflections of at least 0.080 in. being found between loaded and unloaded conditions of the ship. Axial vibration in two ships was traced to the four-blade propeller, which was replaced by a five-blade propeller. The design has been changed to give a rigid single flange coupling; the method of forging the shaft was changed and the forgings are now normalized and the fillets of side crankpin and main journal, which were almost opposite each other, are no longer recessed.

In their conclusions, the authors state that two apparent causes of the failures, *viz.*, the recessed fillets and flexible coupling, are features found on many Doxford engines still running satisfactorily. Failures have only occurred when crankshafts have been subjected to exceptional circumstances, such as misalignment of the bedplates and crankshafts, stresses due to torsional or axial vibration, or defective forgings. The importance of the adjustment of bedplates and crankshafts, of periodical examination of holding-down bolts and chocks, and of the strength of tank tops and engine seatings is emphasized.

Oil-mist Detector

The Graviner high-sensitivity detector has been developed from experience gained with the Graviner-B.S.R.A. Diesel engine oil-mist detector. The refined instrument is intended to give warning of incipient mechanical failure as well as of explosive conditions. It is suitable for use with engines up to 500 H.P. per cylinder or 3,000 H.P. total, turbocharged or normally-aspirated. A temperature rise in a bearing or other working surface, or blow pass from a broken piston ring is reflected in a local increase in the density of oil mist above the average for the crankcase. The instrument automatically compares the density of samples of oil mist from each chamber with that of the average of the crankcase as a whole and gives audible warning of any local increase. A separate indication of the overall oil-mist density within the crankcase gives warning of explosive conditions within the crankcase.

Silicon in Cylinder Liners

It is well known that high-silicon irons have good resistance to corrosion, and it often appears to have been assumed that when, for reasons of foundry technique or for optimum abrasion resistance, the silicon content of a cast iron was increased towards the 1 to 3 per cent range, the resistance to corrosion and corrosive wear would be increased. The examination of a large number of marine Diesel engine liners which have suffered excessive corrosive wear appeared to indicate that, on the contrary, silicon might have a deleterious effect on corrosion resistance. This problem is discussed by Mr. R. Graham in his paper on "Influence of Silicon in Cast Iron on Corrosive Wear." The results of tests show that more often than not, the selection of a higher silicon content than normal, for reasons of foundry technique, will yield a cast iron of poor corrosion resistance. Corrosion resistance can be most readily ensured by keeping the silicon content low, if possible below 1 per cent. Most tests were done with a cast iron of fully pearlitic microstructure and graphite flakes of fairly large size as commonly used in Diesel engine practice; there is no direct evidence that the results are valid for other types of microstructure.

Peak Pressure Measurement

In the M.T.Z. of April, 1960, a report is published on some comparative tests on different types of indicators and gauges used for measuring peak cylinder pressures in marine Diesel machinery. A four-stroke cycle engine developing 50 H.P. per cylinder at 300 rpm was used for the tests. The instruments tested were two mechanical indicators, one with a helical spring and one with a cantilever spring; two electrical gauges, one of the inductive type and the other a piezo type; a "Haenni" peak-pressure indicator and a specially designed indicator which served as a standard for comparison. This latter is described in detail and incorporated a fuel-injection pump valve and a calibrated mechanical type pressure gauge.

The electrical indicators gave readings approxi-

mating to those given by the reference gauge; the other instruments have high readings. Possible causes of the discrepancies are discussed.

NUCLEAR POWER

A summary of recent progress in marine nuclear propulsion is given by Mr. J. S. Burkitt in *Nuclear Power* (August, 1960) in an article entitled "Nuclear Merchant Ship Survey"—there are 41 references.

In this country, interest is principally focussed on the indirect-cycle boiling-water reactor and on the organic-moderated reactor. Of the five groups working in Western Germany, the greatest progress has been made by one mainly interested in the organic-moderated reactor; preliminary design work on a reactor for a 10,000 H.P. research vessel has been completed, and it is now intended that this should be a 15,000-ton tanker planned for completion by 1963. The intention is to power it successively by an organic-moderated reactor, a boiling-water reactor and a pressurized-water reactor. A high-temperature gas-cooled reactor is also being investigated.

A Danish group (Danatom) have carried out a design study on three 65,000 tons deadweight tankers with 25,000 S.H.P. normal (27,500 S.H.P. maximum) single-screw propulsion machinery and a service speed of 16¾ knots. One will be powered by pressurized-water reactor generating steam which at the turbine stop valve will be 427 psi at 451 deg F., this is the nuclear tanker *Alpha*. For the steam tanker *Alpha* the power plant is a Pametrada designed turbine taking steam at 597 psi and 851 deg F.; while for the motor tanker *Alpha* the power plant is a B. & W. single-acting, 12-cylinder, turbo-charged Diesel engine. Figures giving the comparison of the three installations are given in Table V.

TABLE V

	M.T. *Alpha*	S.T. *Alpha*	N.T. *Alpha*
(*a*) Ratio of building cost	1.00	1.03	1.41
(*b*) Ratio of operating cost	1.00	1.10	1.41
(*c*) Days out of service per year (used in estimating (*b*)) ..	28	21	30

In Norway and Sweden the main interest is in the boiling-water reactor and the advanced gas-cooled reactor is also receiving attention in Sweden.

With the *Savannah* nearing completion, the United States Atomic Energy Commission hope to have a second project, a 43,000-ton tanker, ready for sea by 1964 and design studies for a direct-cycle boiling-water reactor, an indirect-cycle boiling-water reactor and a pressurized-water reactor have been evaluated. Considerable interest has been shown and work performed on the design of an advanced gas-cooled reactor coupled to a closed-cycle gas turbine.

MBWR and MGCR

Two reactor power plant groups with considerable potential and many advantages are the marine boiling-water reactor (MBWR) and the maritime gas-cooled reactor (MGCR). The case for the MBWR is put by Mr. V. A. Mize, Mr. B. G. Voorhees, and Mr. Weinzimmer in a paper prepared for the Philadelphia section of the American Society of Naval Architects and Marine Engineers, entitled "Marine Boiling-water Reactor Nuclear Propulsion System for 60,000 Deadweight Tanker." After discussing the feasibility of the MBWR for marine application from safety and reliability aspects, reasons are given for the selection of the natural circulation direct cycle in preference to four other possible cycles. There appear to be advantages in capital and fuel costs, in the weight and overall height of the plant. The nuclear steam supply system delivers steam direct to the propulsion turbine at 980 psi saturated. The returned feed to the reactor core would be at 264 deg F. and generation pressure is 1,000 psi. Although the turbine is designed for remote control, radioactivity levels at part-load during start-up and shut-down will be low enough for local control.

The problems associated with wetness in steam turbines are again receiving attention owing to the development of nuclear steam raisers which necessarily generate saturated steam. A detailed review of this subject is given by Mr. B. Wood in a paper entitled "Wetness in Steam Cycles," read before the Institution of Mechanical Engineers in February, 1960.

The attraction of the MGCR are set out by Mr. H. L. Browne in an article in the first issue of the *Gas Turbine* (January, 1960). This type is being developed by the General Atomic and Electric Boat Divisions of the General Dynamics Corporation (U.S.A.). The reactor core consists of beryllium-oxide moderator blocks containing the fuel elements. The U-235 is of 5 per cent enrichment and a core life of over five years at full power is expected. The coolant gas is helium with an outlet condition of 800 psi at 1,300 deg F. The turbine machinery consists of l.-p. and h.-p. compressors mounted on the same shaft and driven by the h.-p. turbine; the separate l.-p. power turbine is mounted in line with the h.-p. shaft and will deliver 22,000 S.H.P. at 8,000 rpm. The l.-p. turbine exhaust regeneratively heats the h.-p. compressor discharge and then passes through a pre-cooler to the l.-p. compressor inlet. There is an intercooler between the two compressors. The Mark I version, which is to be ready for test in 1964, is expected to have a cycle efficiency of 27 per cent and it will be followed by the Mark II with 40 per cent cycle efficiency operating at higher temperatures and pressures and developing 30,000 S.H.P.

The use of a closed-cycle gas-turbine system results in great flexibility of operation. When varying

output, the transient thermal stresses in the plant components are low because the gas has a low heat transfer coefficient and the lightweight machinery has little heat capacity. Start-up time is much shorter than that of any steam plant. Moreover, the inherently high efficiency can be maintained over a wide power range if control is effected by varying the amount of the gas in use.

The safety characteristics are good. The heat capacity of the core is great enough to permit a delay of between half an hour to an hour after circulation failure before emergency cooling is necessary. The requirements for the containment vessel are less exacting than in the case of a pressurized-water reactor, because less energy is stored in the coolant.

Further advantages of the MGCR system are the low specific weight (little more than that of conventional machinery without fuel); substantial reductions in fuel costs due to high efficiency and excellent neutron economy; and simplicity of operation and maintenance with the prospect of almost complete automation.

Control and Instrumentation

The October issue of the *Journal of the Joint Panel on Nuclear Marine Propulsion* contained a paper by Mr. R. Anscomb and Mr. F. Hutber entitled "The Control and Instrumentation of a Marine Reactor." The authors point out that the behavior of reactors under transient conditions is not yet fully understood so that design of control and instrumentation systems for them is still in an early stage of development. This is particularly so for the more advanced type of systems, some of which offer the best development potential for marine propulsion purposes. For this reason the paper does little more than outline the nature of the problem and describe fundamental reactor characteristics which must be taken into account, and the basic mathematical equations used in designing a reactor control system. It points the way to possible solutions in particular cases and gives a general description of a typical control and instrumentation system which might be used on a ship.

Lloyd's Register Rules

Lloyd's Register of Shipping have issued provisional Rules for application to nuclear-propelled ships. Provision is made for new ideas and for some time the requirements will be subject to continuous review. Welded construction must be used for structures bounding the reactor compartment. Reactor components must be able to withstand a shock of 3g in any direction. The reactor compartment must be gastight, isolated from cargo spaces and, in way of it, a double bottom of at least 6 ft in depth is necessary. The bottom shell in way of the containment vessel must be able to withstand severe local damage without prejudicing the support of the reactor. Other points mentioned concern pressure vessel design and materials, pressure relief systems, reactor engineering, reactor core, fuel elements, reactor shut-down, shielding, effluent disposal, emergency power and maintenance.

STEAM TURBINE AND BOILERS

T.S.S. Windsor Castle

The T.S.S. *Windsor Castle* is the first large British passenger ship to use steam at 950 deg F; the superheater stop valve conditions are 600 psi at 950 deg F, and the turbine stop valve conditions are 540 psi at 940 deg F. The service output of 45,000 S.H.P. is delivered at 115 rpm to two propellers by two sets of Pametrada designed turbines. Each set consists of h.-p. and l.-p. turbines arranged side by side and driving a main gear wheel through double-reduction double-helical articulated gearing (h.-p. and l.-p. astern turbines are provided). The h.-p. turbines have 10 stages, all impulse and the l.-p. turbines have nine stages, the first four of which are impulse, the remaining five being reaction. The underslung condensers have a total tube area of 35,000 sq. ft.

Three main boilers of Selectable Superheat type supply a maximum output of 156,000 lb per hour each, the service output from each being 125,000 lb per hour for a speed of 22½ knots (45,000 S.H.P.). At the reduced speed 19 knots (27,000 S.H.P.), for the ship's immediate schedule, only two boilers are required. In port, the main boilers are shut down and an automatic auxiliary boiler supplies the steam required, while three 1,000-kW Diesel-driven generators supply auxiliary power. At sea, three 1,500-kW turbo generators are available for supplying auxiliary power.

The feed circuit provides for four stages of feed heating using bled steam, together with a split economizer system and two stage steam air heating taking the air to 320 deg F. Efficiency of operation is maintained at both 27,000 S.H.P. (two boilers) and at 45,000 S.H.P. (three boilers) by providing a choice of bleed points. Each set of turbines has five bleed outlets, three of which are common to both powers, choice of one of the remaining two is governed by which power is being delivered. There are two large and one small feed pumps; each large pump can supply three boiler operation and the small one can supply two boiler operation. The auxiliary exhaust range is automatically controlled to remain at 15 psi under all conditions.

The maneuvering platform gauge board has all the recording and measuring instruments grouped together and incorporates line diagrams of the various systems. Remote control of the fuel valves is by hand-hydraulic systems.

All heat exchangers carrying salt water have cupro-nickel tubes and all salt-water piping is of aluminum-brass. All three main boilers have Howden-Vortex wet type dust collectors and fully-automatic sequence-controlled air-puff soot blowers;

there is a permanent fresh-water system for tube washing. For feed make up a Deminrolit plant is installed, which will completely remove CO_2 and remove mineral salts from once-distilled water at a lower cost than that of a second distillation.

T.S.S. Canberra

With the safe launching of the passenger liner *Canberra,* interest in her machinery installation increases. The turbo-electric main propulsion machinery is designed for a maximum continuous power of 85,000 S.H.P. at 147 rpm, although normal service power is 68,000 S.H.P. at 136.5 rpm. The choice of turbo-electric machinery was influenced by special considerations; for many years the owners have run their turbo-electric ships on one set of generating machinery during parts of a voyage where low speed is required to avoid a night arrival. Fuel economy under such conditions is very good with turbo-electric machinery, and overall reliabiliy is probably the highest of any installation. The use of electrical transmission has made it possible to employ relatively high steam conditions without the need to make special provision against thermal stresses when running astern.

The boiler room is abaft the engine-room and over the shaft tunnels. The three main boilers are the largest marine units yet built; they are of Foster Wheeler design, built by Messrs. Harland & Wolff, Ltd., and are of the external superheater D-type. The superheaters receive heat by convection only and superheat control is effected by an air attemperator consisting of a bank of extended-surface tubes through which the steam flows between the first and second passes of the superheater. Combustion air is used as the cooling medium and the proportion that flows across or by-passes the attemporator is controlled by a damper. The design data are given in Table VI.

TABLE VI

	Main Boilers (each)	Auxiliary Boiler
Normal evaporation (lb per hour)	175,000	40,000
Maximum evaporation (lb per hour)	260,000	50,000
Steam pressure (psi gauge)	750	750
Steam temperature (deg. F.)	960	900
Feed temperature (deg. F.)	240	250

The boilers have full air casings to suit operation with forced draft only. External water washing arrangements are provided for tube cleaning and there is a vacuum plant for removing deposits from tube nests, superheater and economizer banks, and uptakes.

Each of the main boilers is fitted with eight suspended-flame oil burners supplied by Associated British Combustion, Ltd.; the auxiliary boiler has three such burners which are arranged for both pressure jet and steam assisted atomization in order to increase the control range, to assist maneuvering, and to give compact flame even when burning the 6,500 seconds Redwood oil for which the system is designed. The burners have two swirlers, the main purpose of which is to induce a series of controlled reversals of air flow, which in turn develop a large number of toroidal vortices into which the atomizer injects the fuel. The primary flame is established about 3 in. to 4 in. in front of the primary swirler and the secondary flame is closely matched to it, the quarl at the mouth serving as an air deflector is not touched by the flame.

For the first time in a British merchant ship the main steam range will be all-welded between the boiler and turbine stop valves. Each of the two unidirectional single-cylinder turbines has 17 stages and drives its alternator through a bellows type coupling. The alternators have two-pole turbo-type rotors, generating three-phase A.C., their rating being as follows:

kVA	rpm	c.p.s.	Volts at unity power factor	Working
32,000	3,087	51.5	6,000	1 alternator—1 motor
30,700	2,400	40.0	4,640	1 alternator—2 motors

For full power working the port and starboard alternators are each connected to their corresponding propeller motor, while for powers up to 40,000 S.H.P. either alternator can be connected to both propeller motors.

The propeller motors are of double-unit design, each consisting of two synchronous machines which are electrically separate. They have salient pole rotors, with squirrel-cage windings in the pole tips for starting and maneuvering as induction motors. Each machine has a closed air cooling system with salt-water secondary cooling. The propellers can be synchronized by connecting one motor of each double unit to one alternator and the other motor of each double unit to the other alternator, A Selsyn indicator shows the relative positions of the two propellers to enable the locking in synchronism to be done at the blade relationship which will excite least possible hull vibration. Closed circuit television provides watch keeping positions and the chief engineer's office with a "live" view of essential gauges.

Of considerable interest is the turbine supervisory equipment which follows power station practice in maintaining a continuous record of the mechanical behavior of the turbine. The differential expansion of the stator and rotor, the eccentricity of the rotor, the rotor speed, and the vibration at a number of positions are all continuously recorded; and, in addition, meters on the turbine gauge panel indicate the effects of changing steam conditions. A feature of this supervisory equipment is the small size of the sensing heads. All the circuits are transistor operated and each is built as a plug-in subassembly for easy replacement; there is 15-volt

plug-in power pack. Differential expansions as small as 0.005 in. can be measured, and an eccentricity of 0.001 to 0.002 in. can be detected. The vibration sensing heads detect defects in rotor balance, alignment and bearing condition.

300,000-S.H.P. Exercise

During the year, an article entitled "Machinery Proposals for a Mammoth Liner" (*Marine Engineer and Naval Architect,* April, 1960) discussed a proposal put forward by the Heavy Plant Division of Associated Electrical Industries, Ltd., for the propulsion machinery of a very large passenger liner requiring a total of 300,000 S.H.P. In the June issue of the same journal an alternative to the suggested turbo-electric drive was put forward by Dr. T. W. F. Brown, of Pametrada.

The A.E.I. proposal is to install two 150,000-S.H.P. cross-compound reheat turbo-alternator sets taking steam at 1,500 psig and 1,000 deg F with reheat at 360 psig and 1,000 deg F., to supply five double unit synchronous propulsion motors, each having an output of 60,000 S.H.P. at 250 rpm. Each turbo-alternator set would comprise two shaft lines, mechanically independent, coupled electrically (and by steam flow). An 11-stage h.-p. turbine, three stages of the i.-p. turbine, a six-stage dual flow l.-p. turbine and a 56,860 kW two-pole air-cooled alternator form one part of a generating set, the other half comprising an exactly similar alternator driven by a 12-stage section of the i.-p. turbine and a six-stage dual flow l.-p. turbine. Six bleed points are indicated leading to a feed temperature of 435 deg F.

The Pametrada proposal is based on four screw propulsion for such a ship with 75,000 S.H.P. per shaft at 220 rpm. The steam conditions would be 1,000 psig with reheat after h.-p. turbine exhaust at 250 psig to 1,010 deg F. Each set comprises a seven-stage h.-p. turbine and an eight-stage i.-p. turbine in tandem, both rotating at 4,200 rpm and coupled to the main shaft by double-reduction locked train gearing. The two nine-stage double-flow l.-p. turbines, rotating at 3,800 rpm are each coupled to the main shaft by single-wheel gearing. Three bleed points are indicated with a final feed temperature of 380 deg F.

The fuel consumption of both installations is practically the same and, including a "hotel" load suitable to this class of ship, the all-purpose fuel consumption is estimated at 0.426 lb per S.H.P. hour. The geared turbine installation shows a saving of weight of 1,000 tons or more. Details of the design, flow charts and some of the arguments pro and contra electric drive are given in the two articles referred to.

Evaporators

The production of fresh water on board is now considered an essential requirement in most ships for both domestic and boiler feed purposes. Two papers have recently appeared on this subject (*a*) "Flash Evaporators for the Distillation of Sea Water," by Mr. A. Frankel; Institution of Mechanical Engineers, and (*b*) "Distillation for Marine Purposes," by Mr. R. G. Peaver. In paper (*b*) the author describes the various types of distilling plant in current use, recent improvement and the various factors which need to be considered when selecting distilling plant for a particular purpose. Scale and feed treatment problems are dealt with and the attraction of flash evaporation is pointed out. In paper (*a*) the thermodynamic principles on which the flash evaporator operates are described and some of the reasons for its recent emergence are explained. It is shown that the performance of a flash evaporator is much less dependent on the number of stages used than is the case for a submerged coil unit. Losses due to use of a finite number of stages and the effects of other unavoidable losses are described and discussed. Actual designs of evaporator vessels are described showing means of avoiding inter-stage piping or ducting despite the use of a large number of stages. The advantages of flash evaporation are seen to be very great.

In an article published in *The Shipbuilder and Marine Engine-builder,* March, 1960, entitled "Flash Evaporators in Service," is described a plant designed to utilize the heat in the main Diesel engine cooling-water in a single-stage flash evaporator. The heated sea-water passes through nozzles into a high vacuum chamber where it flashes off, the vapor being led to a distiller and the unevaporated brine being pumped away. The care needed in the selection of pumps for such plant is emphasized. Experience indicates that steadier vacuum conditions are produced by using an air pump rather than steam-jet ejectors, particularly when these are supplied from an exhaust-gas boiler.

The final stage of conditioning "made" water for high-pressure boiler feed purposes is now most satisfactorily done by a demineralizing process following initial evaporation. Several proprietary makes are available and all aim at the complete removal of scale forming salts, silica and acid radicals (including CO_2 of course). This is carried out by adsorption and surface reactions as the feed is passed through beds of special synthetic resins. These resins are very stable and can withstand prolonged attack even by such reagents as concentrated sulphuric acid and concentrated caustic soda. With a reasonable purity of distillate from the evaporator and correct sizing of the plant, regeneration of the resin beds should only be required every three months (or longer); it is easily carried out using sodium hydroxide and sodium chloride. Such equipment is fitted in the passenger liners *Canberra, Oriana* and *Windsor Castle.*

MISCELLANEOUS

Liquefied Natural Gas

Considerable information has been forthcoming

on the subject of sea transport of liquefied natural gas. Two sources in particular are mentioned here: (*a*) "Methane Transportation by Sea," by Mr. E. C. B. Corlett and Mr. J. F. Leathard, read before the Royal Institution of Naval Architects in March, 1960, and (*b*) "Design of Aluminum Tanks for Sea Transport of Liquefied Natural Gas," *Shipbuilding Equipment,* May, 1960.

In paper (*a*) the authors deal with the properties and liquefaction methods of methane, its sources and markets and the economic significance of its transportation by sea. Methane tankers will be large in relation to their methane deadweight. They must have ballast capacity which cannot be used at any time for methane; oil could be carried as cargo and also act as ballast; a double bottom is essential and the hull must have a fairly full form. Because of the large freeboard exposed to wind, the vessels should be twin screw and have twin rudders.

A lower gas boil-off than 0.3 per cent per day requires a prohibitive thickness of insulation, and various ways of dealing with the boil-off are discussed. Other items mentioned are piping and pumping systems, loading and discharging methods, safety and inspection, explosion hazards, structural danger from brittle fracture following a leakage, tank damage from thermal stresses, access for inspection, and repair.

Tank design and insulation are discussed in some detail. This aspect is also discussed in paper (*b*). The choice of materials is virtually limited to aluminum, austenitic steel and copper. Copper is at least 30 per cent more expensive than aluminum and is only used for small containers. The two most suitable materials appear to be a nickel-chromium steel to ASTM A-353 and the British NP5/6 aluminum-magnesium alloy.

Paper (*a*) concludes with some estimates of wellhead liquefication and other costs. For a 10,000-ton methane carrier (required to be a ship about the size of a 30,000-ton tanker) the building cost per ton of methane deadweight is estimated to be £350 and the cost of transport between Algeria and the United Kingdom, or Venezuela and the United Kingdom would be about 0.3 to 0.4 pence per ton-mile.

Explosion Hazard in Tankers

Since 1957 there have been a number of unexplained explosions in crude-oil carriers; a factor common to several of them was that the ship was engaged in tank cleaning after recently discharging cargo. An investigation was undertaken and the present findings were presented before the Institute of Marine Engineers in May, 1960, in a paper entitled "Gas Concentrations in the Cargo Tanks of Crude Oil Carriers," by Mr. A. Logan and Mr. J. W. Drinkwater. The investigation was not concerned with the possible sources of ignition, but was aimed at determining the circumstances in which the tanks may be in an explosive condition and the factors affecting this condition. Much valuable information is given concerning ullage-gas analyses. There are two periods when tanks may be regarded as non-explosive: during the loaded voyage, when the gases are well above the upper explosion limit; and after thorough washing and gas-freeing on the ballast passage. During loading, the tanks pass quickly through the explosive zone, although normally only a small layer of any tank will be explosive at any given moment. During discharging, tanks may become explosive, but it is in the period between discharging and the end of tank cleaning that the greatest variations occur and that the tanks are most likely to be in the explosive range for considerable periods.

Continuously recording equipment has been developed to investigate the effects of cleaning processes on ullage gases and gas strength measurements have been examined for six basic ways in which a tank may be treated during the ballast voyage:

(*a*) Dispense with washing and gas-freeing, the tanks being battened down immediately after discharging; the explosion hazard is small, irrespective of strength.

(*b*) Washing followed by gas freeing will produce a safe tank, but an explosive mixture is frequently present during washing.

(*c*) Washing without gas freeing leaves tanks in an explosive condition apparently indefiintely.

(*d*) Gas freeing without washing is not practicable.

(*e*) Gas freeing before washing gives no success.

(*f*) Gas freeing before and during washing gave encouraging results.

Some methods of gas freeing are described and discussed.

The authors indicate the three ways in which explosive mixtures can be avoided during washing: by ensuring that the gas concentration is too rich; by reducing the oxygen content with inert gas; by ensuring that the oxygen-gas mixtures is too weak. Reasons are given for rejecting the "too rich" system. Inerting probably gives the most complete protection but is a complicated method. The "too weak" method shows promise and work is continuing along this line.

For ships at sea: security

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SPERRY

BESSE B. DAY

RELIABILITY ENGINEERING

THE AUTHOR

earned her B.S. in Mathematics at Missouri State College, Warrenburg; and her M.A. in Mathematics and Statistics at the University of Michigan. Worked thereafter principally in the application of statistical techniques in research, development and quality control of production in the fields of engineering and forestry. 1927-29 Victor Talking Machine Company; 1930-43 U. S. Forest Service; 1943-47 the Johns Hopkins University Applied Physics Laboratory, on the development and production of the radio proximity fuse; 1947-1954 head of Statistician's Office, U. S. Naval Engineering Experiment Station, Annapolis, Maryland; presently Consulting Statistician to the Chief of the Bureau of Ships, with additional duties as Head, Statistical Engineering Section, Research and Development; Fellow American Statistical Association and American Society for Quality Control; member of the International Statistical Institute; Past Chairman of the Section on Physical and Engineering Sciences of American Statistical Association; past member of Executive Committee of ASQC; published and given papers on applications of Statistics to engineering problems. 1954 Am. Stat. Assoc. Program Chairman; 1957 Brumbaugh Award winner for paper in Industrial Quality Control judged to have made the greatest contribution to the development of industrial applications of statistical quality control; member Washington Academy of Science; July 1, 1960 the Association of Senior Engineers of Bureau of Ships. In 1959 was married to C. E. Mauss but retains original name for professional purposes.

CONCERN FOR RELIABILITY and efforts to achieve it are not new. They are as old as industry itself. However the development in recent years of more and more complex equipments and systems, combined with the rapid extension of the "art" resulting in a design becoming obsolete before it is scarcely off the drawing board, have produced reliability problems unsolvable by the old methods. The problems have become of such magnitude as to demand a new and specialized approach.

Government and industry began a broad attack on the reliability problem in 1950-51. General George C. Marshall, then Secretary of Defense signed a directive dated 12 September 1951 which pointed out the results of a survey made by the Ad Hoc Group on Reliability of Electronics Equipment [1] and placed emphasis on reliability efforts not only on Electronics equipment but in all other areas. Two examples will serve to emphasize the fact that problems exist in other than Electronics equipment.

(a) The diameter of propulsion shafts in destroyers was reduced to take advantage of the added strength of alloyed steel. No testing was done before release to production. Two failed and the propellers were lost. All of the shafts of this type

had to be replaced. The price of this correction was $6,000,000. Preliminary reliability testing of the revised design would have prevented this situation.

(b) The Navy ordered soldering guns (the type —with a transformer in the butt—that looks like a space-age pistol). These reached the fleet and one was signed out by an engineering officer. This officer was of the inquisitive type so he disassembled the gun to see how it worked. In doing this he uncovered a major design failure—a safety hazard which practically guaranteed the electrocution of many Navy men. Again, testing for reliability before release to production would have prevented the situation.

Why did the interest develop at this time? Reports showed that in 1949 about 70 per cent of Navy electronic equipment was not functioning properly; during World War II as much as 60 per cent of airborne equipment shipped to the Far East was found to be damaged upon arrival; furthermore 50 per cent of equipment and spares in storage became unserviceable before they were ever put to use.

The effect of complexity of modern equipment on reliability is illustrated by Figure 1. Thus if the average reliability of a given part is 99 per cent, a system of ten such parts will have an estimated over-all reliability of 90 per cent. With 200 such parts the reliability drops to roughly 15 per cent, and with 400 parts there will be less than 5 per cent reliability. The same study indicated that the primary source of trouble was in the area of *engineering design*. For this reason, efforts to improve reliability became concentrated mostly in engineering design and reliability came to be accepted as a design parameter. Reliability must be built into a product from the design stage; there is no other way to achieve it. The Secretary of Defense recognized this by establishing in 1960 under the Director of Defense Research and Engineering, a "Program to Improve and Assure Operational Reliability of Defense Material". While Reliability Engineering is thus recognized as primarily a design function reliability efforts must be extended to procurement, manufacturing, storage, field evaluation, maintenance, and in-service use if the inherent reliability provided in the design is not degraded.

In seeking solutions to the problem of reliability there has developed an orderly discipline which is a combination of reliability theory (statistical and mathematical) engineering and administrative techniques. This discipline is now recognized as Reliability Engineering. As yet, however, the techniques of this new branch of engineering have not been formalized into sets of rules, regulations, standards of practice, nor reference manuals. For this reason a paper covering the essentials of Reliability Engineering seems to be justified. It should help to bring into focus what is now a very confusing picture. Because reliability is not a new term many misconceptions have developed concerning it. In particular it has not been recognized for what it is, a discipline separate and apart from either Quality Control or Quality Assurance. To repeat what has already been said the primary effort in reliability engineering will be concentrated in the design stage if it is to be successful. The tools needed by the design engineer in developing a reliable design depart drastically from those required by the production and maintenance engineer to insure that the reliable design characteristics have not been degraded.

The stages of reliability effort in the time-cycle sequence of an equipment or system are enumerated below. The subsequent efforts to insure the reliability designed in the apparatus are not included here.

1. Prepare invitations for technical proposal.
2. Evaluate technical proposals.
3. Prepare contract specifications.
4. Detailed design study.*
5. Pre-prototype stage.**
6. Prototype stage.†
7. Preproduction stage.
8. Demonstration of service readiness.
9. Service evaluation.
10. Full-scale production.
11. Operational and product improvement stage.

The essential tasks for achieving reliability are:

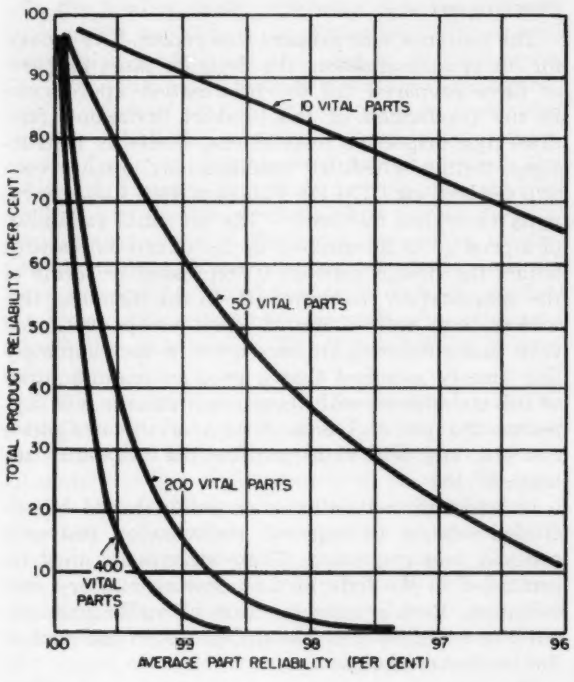
1. Specifying reliability requirements.
2. Feasibility study.
3. Detailed design study.
4. Testing program.
5. Design review.
6. Preproduction demonstration for top-management.
7. Final report.

These seven tasks are developed as follows:

Specifying reliability requirements

Complete information for designing the system or equipment, based on the proposed operational use, is furnished to the responsible contractor or Governmental agency. This should include: environmental conditions, such as extremes of temperature, pressure, humidity, stress, shocks, strains, etc.; human factors and/or service conditions which might significantly affect reliability; and all available historical data on previous failures of similar or identical systems or equipment. A *numerical requirement for service use* is also provided at this time. This numerical requirement provides the designer a definite goal rather than a mere statement that

* The detailed design study phase begins with the awarding of the contract and continues until the initiation of detailed design.
** The pre-prototype stage begins with detailed design work and terminates with essential completion of initial design.
† The prototype stage begins when the first set of hardware is available for assembly as a complete system.



From "Steel" 2/27/60

Reliability is more than a new word for quality control. Missiles spawned the new science and brought charts like this one into being. It graphically demonstrates the principle that simple machines are more reliable than complex ones. Scientists and engineers skilled in the mathematics of probabilities can predict within well-defined limits how well each part and each device or assembly will perform. Their scientific crystal gazing is couched in terms called reliability factors.

Figure 1

reliability must be built into the system or equipment. Department of Defense officials and the Congress are insisting that reliability be placed on a realistic basis.

Lord Kelvin has aptly stated the case for a numerical requirement: "I often say—that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be."

However, though it is desirable to design and produce equipments and systems that are perfectly reliable, we must be fully cognizant that this is not a realistic approach; perfection is unattainable. There will always be an element of uncertainty. *There are sometimes failures: equipments and systems do fail.* This is a reality which must be faced. Quoting from [8] "*After use* Reliability can be determined as a certainty. *Before use it may only be expressed as a probability.* Thus for practical purposes *reliability* is essentially a statistical concept. It is not surprising that statistical techniques and the statistical point of view generally have an important part to play in achieving the degree of confidence required."

This inevitably leads to the standard definition for reliability, the definition acceptable to the experts in Reliability Engineering—"Reliability is the probability of performing without failure a specified period of time." Reliability will be specified in different ways, depending upon the functional differences in system or equipment operational use and the impact that failure in service may have upon tactical or mission accomplishment.

Feasibility study

This is a reliability analysis of possible design approaches, to identify the basic design concept which will most readily yield the required reliability. Existing historical data based on known failures, should be used to provide valid information for evaluating and comparing alternate design. Environmental factors and safety margins must be considered.

At this point the first predictions or estimates of reliability should be made. These will be derived mainly from analytical prediction techniques since little or no data are available. It is to be expected that this first prediction will not inspire a high degree of confidence, but as the design work progresses there should be continuous evaluation of reliability with a corresponding increase in confidence.

In principle, reliability prediction is not new, nor is it uncommon. Everytime an engineer releases a drawing to Production he is predicting that the design being released has a high probability of doing the job it was intended to do. What is new is the recognition that in dealing with large and complex systems made up of a combination of parts (possibly electrical, mechanical, and electronic components in one system) each part or sub-system will have its own life expectancy. It then follows that the total for the system must be evolved from these individual numerical values.

Detailed design study

With adoption of a general design concept, the design engineer will proceed with the detailed development of the design. Again, environment must be given careful consideration in the proper selection of parts, components, and material. Critical or borderline parts where performance range is near the specified extremes, or those having a special impact on the total reliability, must be taken into account. If test data are not already available, test programs may need to be planned and executed.

Human engineering factors in manufacturing, inspection, maintenance, and operation must also receive attention. In determining optimum design a balance will be achieved between reliability and such other parameters as weight, size, accuracy, performance, serviceability, producibility, maintainability, etc. Consideration should be given to possible interaction between sub-systems and the overall effect of such interactions on the reliability of the system. At this stage, redundancy may be useful in attaining the desired reliability. Simplicity is also desirable. Finally, a precisely stated prediction of reliability attained will be made on a continuing basis. The reliability predictions will be revised as design changes are effected to correct errors or weaknesses. As the design approaches finalization, confidence in the numerical reliability prediction will increase because it will be based on a growing accumulation of test data.

An important by-product of the reliability prediction is the thorough and objective analysis of the design required to derive the prediction. This analysis acts as a screening process for design oversights and marginal applications and provides some assurance of design reliability. It is extremely advantageous for the design engineer to be familiar with the statistical principles used in prediction techniques and that he realize that these techniques are an essential part of his working equipment.

Testing Program

Too often this phase is either completely ignored or inadequately performed. The outlay of time and money for testing may appear unnecessarily costly but will present savings in the long run. The example of the propulsion shafts is a case in point. Testing the revised design, based on environmental-use conditions, would have uncovered the inherent weakness in the changed design with a resultant saving in the amount of funds required to correct the design error.

Design review

This review should be undertaken by competent personnel experienced in the major engineering areas of the specific design. Those responsible for the review must not have had responsibility for any phase in the creation of the design. Such reviews may begin early in the design stages, depending upon the complexity of the design itself, and continue through completion of the final acceptance test (the developmental cycle to final acceptance). Design review should not be considered a reflection on the work of the designer, but rather as an added precautionary measure in reliability control.

Preproduction demonstration for top-management

This is the final demonstration that the design is ready for acceptance and production, that a specified reliability has been attained.

Final report

The designer will prepare this report. "As a basis for his recommendation the designer must prepare, or have prepared, all the information appropriate to the production of the product, including final drawings, inspection instructions, assembly instructions, testing schedules, specifications, quality control criteria, etc." [8] Dr. Paterson, Bell Laboratory, aptly expresses the need: "The potential reliability of a product is determined by the effectiveness with which the design concept is expressed in terms of the specification requirements. In the ultimate, this means that each material, each component, and each manufacturing process must be so completely and clearly specified that a product manufactured in full compliance with these requirements will represent the physical embodiment of the designer's concept, and will thus provide the reliability intended." [8]

In addition, reliability statements should be included relative to required performance, test procedures, and inspection. These statements must be construed in the light of the covering military specification. Each statement must be sufficiently explicit to preclude possible ambiguity on the part of the vendor or the customer.

The process of production should be concerned only with repeating the product exactly to the specifications and recommendations of the designer.

If it is clear that the product cannot be manufactured to the designer's specifications or that it is not meeting the designer's test and quality-control requirements, the matter should immediately be referred to the designer for post-design services.

Modification to design, however small, should not be introduced during production other than by formal amendment (either by the designer, or with his consent) to the original specification.

The reliability report shall include the following:

1. The predicted reliability of operation of the system or equipment under the anticipated operational environment.
2. The features of the design which are displaying weaknesses with respect to reliability.
3. The measures planned by the contractor (or agency) to correct or overcome reliability weaknesses.
4. Improvements in reliability attained since last report.
5. Conditions of operation to be avoided to assure reliable operation.
6. Quality control procedures and requirements appropriate and necessary to maintain a high standard of reliability. These should be expressed in a manner which would permit their inclusion in specifications for systems and equipment to be produced in quantity.
7. Other reliability considerations as pertinent to systems or equipment subsequent manufacture, use, or maintenance.
8. Plan for test demonstration of reliability achieved.
9. Unique design features expected to contribute to improved reliability.
10. Recommendations for packaging and packing to insure that reliability of systems or equipment is maintained in transport and storage.

In the final analysis, reliability depends primarily upon the individual concerned with the several stages in the life cycle of a system or equipment. The individual must possess motivation and education in order to perform at his optimum level. Nor can any reliability program succeed without management support. Management must believe in the reliability program and must provide the required funding and personnel. Reliability is essentially a management decision. By using the tool of prediction, management becomes aware of the specific level of reliability purchased with each design dollar. Wise decisions can only be made when sufficient information is available. Management must be provided with this.

The technical men at the design level must be made aware of the tools of reliability engineering and instructed in their proper use. They must have an understanding of the statistical concepts for prediction of reliability as well as an appreciation of the contribution made to statistical design and the analysis of experiments in test programs. Finally, the workman must be motivated to the highest standard of workmanship. It therefore follows that a successful reliability program will be founded on two types of training: 1. basic education, and 2. publicity.

In-so-far as the Navy Department is concerned most tasks for achieving design reliability belong, in fact, to the contractor or other design agency. However, technical Bureaus, such as the Bureau of Ships, must undertake certain specific tasks if reliability is to be an accomplished fact. These fall in two general areas.

1. On research and development contracts (design): a. Preparation of requests for technical proposal (1) specifying reliability requirements and (2) providing basic information on operational use, environmental conditions, tics, b. Evaluation of proposals, c. Preparation of contract specification, d. Monitoring progress, e. Evaluation of adequacy of contractor's reliability program, f. Make decision on acceptability of design.
2. In procurement specifications: a. Specify reliability requirements. b. Provide sampling level. c. Determine adequate test program.

The preceding paragraph covered the detailed tasks to be undertaken by the government Bureaus on a specific research and development contract. But some more general tasks are required to assure an effective reliability effort. First, a general standard (or specification) on Reliability is required couched in sufficiently broad language to be applicable to all types of equipment. It would outline reliability philosophy and describe what a contractor's program should be. An initial draft of such a document has been prepared in the Bureau of Ships. Three classes of documents would be needed to implement this general specification.

a. *General Standard on Design Principles.* A standard to cover the basic intrinsic design principles, such as simplicity, redundancy, balance, etc. would be needed. This standard would also be general and equally applicable to all types of systems and equipment in all three Services.

b. *Basic Handbooks.* This class of document would for the most part be specific, prepared within the agency, covering practices for system and equipment types. There may be a need in some instances for handbooks of general application as well. It is anticipated that these handbooks would cover a wide range of subjects.

c. *General Standard for Reliability Testing and Evaluation.* Because testing is an indispensable tool in a program for designing a reliable system or equipment it is essential that the designer be furnished information on the known valid and approved techniques of testing and evaluation. The purpose of testing in development and design is twofold: First, the results of testing provide verifiable proof of performance of proposed apparatus. This takes decision-making out of the realm of engineering intuition and bases it on proven facts. Second, the results of testing provide a real index of the accomplishments of developmental and design effort to prescribed standards. To derive these benefits from testing, it is necessary that the test programs be adequate and proper for the purpose intended. The solution to the problem of valid reliability testing lies in making the proper practices, techniques and principles involved readily available to developmental personnel. This can best be accomplished by compiling what *is* proper into a basic Standard. Contributions to its contents would come from engineering, mathematical statistics, and mathematics.

General Specification on Reliability

Philosophy	Motivation	Parameters
Standard on Intrinsic Design Principles (General)	**Basic Handbooks (Specific and general) information, covering practices, etc.**	**Standard for Reliability and Evaluation (General)**

It is believed that any and all of the documents needed for achieving reliable military material will fit within this pattern.

It would seem desirable to establish under the leadership of R&E (DOD) a task group from the three Services to explore the requirements for official reliability documents and make recommendations for the preparation of those needed to meet the requirements.

SOME REFERENCES ON RELIABILITY

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2. *Proposed Reliability Monitoring Program,* dated April 1958, Office of the Director of Guided Missiles.

3. *A Manual of Reliability* (a 32 page report-special). Product Engineering—16 May 1960.

4. *Reliability of Military Electronic Equipment.* Report by Advisory Group on Reliability of Electronics Equipment, Office of the Assistant Secretary of Defense (Research and Engineering) 4 June 1957.

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7. *Literature Guide on Failure Control and Reliability,* Technical Report No. 13—Stanford Electronic Laboratory, Stanford University, 31 Dec. 1956.

8. *Collection of Papers.* Symposium Reliability of Service Equipment—London, March 1960 (Conf.).

NUCLEAR SHIP TENDER

The nuclear servicing vessel ***Atomic Servant*** has been delivered by Todd Shipyards Corporation to participate in a series of tests and joint operations with the new ***NS Savannah.*** The ***Atomic Servant*** is a 129 x 36 x 14 ft. unpropelled vessel, designed for maintaining, refueling and waste handling operations in conjunction with nuclear-powered vessels. Built at the Houston plant of Todd Shipyards Corporation for the Maritime Administration and the Atomic Energy Commission, she was designed by the Electric Boat Division of General Dynamics Corporation. The 760-ton ***Atomic Servant*** is equipped to receive, process, package and dispose of spent fuel and other radioactive wastes produced by the ***Savannah.*** Principal compartments in the vessel are a fuel pit for handling fuel elements and control rods; a waste processing compartment for handling liquid waste products; a component decontamination and work shop area; a personnel decontamination room; a laboratory and an operations room with control and alarms. She will be manned by 15 highly trained technicians. Todd Shipyards Corporation has been awarded a 5-year contract by the Maritime Administration for the maintenance and repair of the ***NS Savannah*** and for the operation and maintenance of the ***Atomic Servant.***

—MARINE JOURNAL

THERMIONIC CONVERTER FOR NUCLEAR APPLICATIONS

A thermionic converter for direct conversion of electricity in conjunction with nuclear reactors is being developed by the Bendix Corporation.

The company's Red Bank, N. J., division has already developed a cesium-vapor thermionic converter that generates 5 watts of electricity directly from solar energy.

Electrical power is produced by the application of heat to a 1/4-in.-diam, cathode used in conjunction with an anode. The use of cesium vapor permits the spacings between the cathode and anode to be 50 times greater than those of vacuum-type converters—a design that improves reliability and life expectancy, provides simpler manufacturing techniques, and greater resistance to shock and vibration.

—MECHANICAL ENGINEERING

L. W. FERRIS

DEVELOPABLE SURFACES

THE AUTHOR

graduated from the University of California in 1916. After working at several shipyards on the West Coast, came to the Bureau of Construction and Repair in 1925. Since that date has worked continuously for the Navy Department, contributing to the design of a wide variety of ships. At present time is a Project Coordinator in the Hull Design Branch of the Bureau of Ships. Author of the following papers: "The Effect of an Added Weight on Longitudinal Strength" Proceedings of the Society of Naval Architects and Marine Engineers 1940. "The Proportions and Form of Icebreakers" Proceedings of the Society of Naval Architects and Marine Engineers 1959.

BACKGROUND

In naval architectural circles one occasionally hears "developable surfaces" mentioned, usually in reference to some portion of a hull and implying that construction is made easy because the plating will lay smoothly on the frames without being forced. The subject of developable surface is an interesting one for those who like geometry, and it has some economic aspects. At the present time when costs of new ships are soaring, the designer should not overlook chances of making some savings through simplifying the structural work.

Actual figures on savings which can be made by using developable surfaces are not easy to find. One case pertaining to sponsons on an aircraft carrier has been investigated and it was found that construction of two sponsons in accordance with the original double curvature design would require forming of the plates at a cost of around $100,000 over that required for an alternative design with single curvature.

Many ships of the United States Navy have been designed with simplified forms above the waterline. Some have been fitted with transom sterns, some have had ruled surfaces in way of side armor plating and some have been provided with chines which enabled large areas of plating to have little or no double curvatures. These features have saved money without detracting from the propulsive efficiency of the ships. Many cruisers of the British Navy have exhibited a chine near the bow, well above the waterline; this is claimed to be beneficial from the standpoint of seaworthiness.

Simplification of the form and introduction of chines below the waterline should be done with caution to insure that there is no significant increase in resistance. In general the chine should follow the line of flow, as determined by a model basin experiment such as is made for determining the position of the bilge keel. Of course the line of flow will not remain constant in service at sea, but the model basin test is the best thing available for guidance.

Some old-timers will remember the straight-

frame ships built in Great Britain during World War I. They were not very handsome but served a good purpose in an emergency. Dr. Robb's paper [1], and the ensuing discussion gives technical information about these ships. It appears that the principal idea was to use straight segment framing which could be readily fabricated by bridge builders in the emergency. It was in the days of riveted construction. Little was said about the ease of fabricating the shell plating. Presumably the straight segment framing caused the plating to be easier to fit although it did not insure that the plating would be developable. The fact that the straight-frame system was not perpetuated after the war suggests that it was not economical in peace time competition.

More recently the "Hydroconic" system of building tugs has been developed in Great Britain and has been widely adopted. According to published articles, an advantage of the Hydroconic form is that the plating is developable and thus easy to fabricate.

The technical press has also described a newly invented form known as the Levingston Standard Bow. It is applicable to barges. Among the advantages claimed for this bow is the elimination of all compound curves and warps thus reducing the cost of construction and repair. It is also claimed that the form is such that all dimensions can be calculated and expensive template work eliminated.

Boat designers have had the matter of developable surfaces forced upon them with the adoption of plywood. This material will not work well unless used on a surface which is developable or very nearly so. Some good graphical methods have been perfected and are applied to insure that surfaces of the boat hull will be developable. These methods depend on trial and error, but with some experience a designer can use them expeditiously. In one method, cone apex locations are assumed and the generating lines of the developable surfaces are drawn as lines converging to the apexes. This method is clearly explained and illustrated in [2]. In a recent paper by R. G. Kline [3], a number of theorems are stated which apply to graphical methods of delineating developable surfaces.

The opportunities for using developable surfaces for ships are generally less favorable than for boats. This is due to hydrodynamic reasons. Motor boats travel at higher speed/length ratios than do large ships and forms with a chine and essentially flat bottom surfaces are suitable for boats, especially when a planing condition is approached. For large ships the possibility of making the structure easy to fabricate is very attractive but requires a most careful investigation of its effects on the ship's performance.

MATHEMATICAL IMPLICATIONS

Starting with a piece of thin, flat material, if one rolls it up in any manner, a developable surface results, for by unrolling the material it will develop into a flat, or plane, form. No internal straining of the material takes place, save the bending about the neutral axis of the thin rectangular section. No stretching or compression of the neutral surface is required.

It is fairly obvious that a developable surface must be a ruled surface, that is, a surface generated by a moving straight line. All developable surfaces are ruled surfaces, but not all ruled surfaces are developable.

The cone and the cylinder are developable surfaces, and, of course, the cylinder may be thought of as a cone of infinite altitude. Now the base of the cone need not be a circle, or even a closed figure; it can follow any arbitrary curve. The cone can be further generalized by continually varying its altitude. Thus it becomes apparent that a wide variety of forms are developable.

Suppose a piece of thin, flat material is knuckled so that it consists of a multitude of plane strips, each joined to the next one along its edge as shown in Figure 1. The object can be flattened out by hinging at the edges. Now if one conceives of the plane strips being made narrower and narrower, the object approaches a continuously curved surface, and in the limit when the plane strips become infinitely narrow, a developable surface results.

There is an exact mathematical definition for a developable surface.

It will be recalled that the equation of a plane involves the three sets of coordinates x, y and z and is of the form—

$$Ax+By+Cz+D=0 \quad \ldots\ldots\ldots\ldots (1)$$

When numerical values are inserted for all of the constants A, B, C and D, the formula represents one specific plane.

The term "parameter" as used in mathematics has a specific meaning. It is a quantity which occurs in an equation and has a constant value in any numerical solution of the equation, but may have different values arbitrarily assigned to it during an investigation. Thus in equatiton (1), if the three coefficients A, B and C are considered as parameters, they can have any conceivable sets of values assigned to represent planes in all conceivable locations and attitudes. Now it is possible to impose some restrictive conditions. If, for example, the condition $A=2B$ is imposed, A and B are no longer independent and the number of parameters is reduced from three to two.

It is possible to impose relations such that A, B and C are all dependent on a single parameter ϕ. This is expressed mathematically by stating that a function of x, y, z and ϕ is equal to zero.

$$f(x,2y,z,\phi)=0 \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Assuming that equation (2) is linear, that is, that it contains no higher powers or products of x, y and z, it represents a family of planes. For each assigned value of the parameter ϕ a specific plane results.

Now suppose that one numerical value is chosen for ϕ. A definite plane results. For a slightly greater value of the parameter, $\phi+\Delta\phi$, another nearby plane results and in general it intersects the first plane. Further incremental steps in the value of ϕ produce additional planes, each of which intersects the preceding plane. The same effect takes place as ϕ is reduced by incremental steps from its starting value. Assigning a large number of successive values to ϕ, there results a multitude of plane strips each joined to its two neighbors along straight lines, just as shown in Figure 1. Taking values of ϕ infinitely close together, there results a curved surface, which is mathematically designated as the envelope of the family of planes. This is a developable surface.

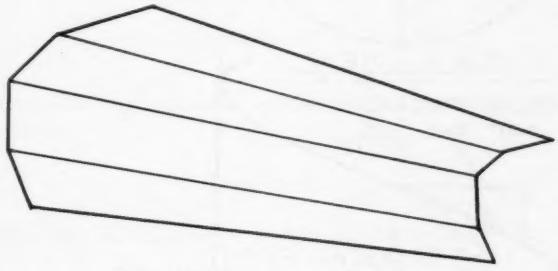

Figure 1

If the family of planes were controlled by two parameters, ϕ and ψ, it would be possible to have one series of planes progressing from a given starting point by varying ϕ and another series progressing in some other direction by varying ψ, and still others by varying ϕ and ψ at the same time. Thus the concept of one series of plane strips would no longer hold and Figure 1 would no longer apply.

The necessary and sufficient condition for a surface to be developable is that it be the envelope of a one parameter family of planes.

The procedure for obtaining the equation of the envelope of a family of planes consists of the following steps.

(1) The equation of the family of planes is written down.

(2) In the second step the parameter is treated as a variable, and the partial derivative with respect to the parameter is written down. This gives another equation.

(3) By solving the foregoing two equations simultaneously so as to eliminate the parameter, the equation of the envelope is produced.

Suppose there is a problem of investigating a surface defined by a given equation. If it can be demonstrated that the surface is the envelope of some single parameter family of planes, then it is proved that the surface is developable.

Three ruled surfaces are illustrated in Figure 2. There is a cylinder, which is generated by a vertical line moving around at a distance R from the Z axis. Inside of the cylinder is a helical surface developed by a radial line rotating about the Z-axis and simultaneously climbing in elevation. The curve traced on the cylinder by this moving radial line is a helix. Outside of the cylinder there is another surface, a helical convolute, generated by the moving line which remains tangent to the helix.

Dealing first with the cylinder, it is obviously a developable surface, but the following steps are taken to show how the mathematical criterion can be applied.

In Figure 3 there is shown the trace of a vertical plane on the X2Y datum. Equation of the plane is $\frac{x}{a}+\frac{y}{b}=1$. A family of vertical planes of this type can be represented by a formula containing a parameter α. Let $a=R\sec\alpha$ and $b=R\operatorname{cosec}\alpha$, Then

$$\frac{x}{R\sec\alpha}+\frac{y}{R\operatorname{cosec}\alpha}=1 \text{ or}$$

$$F=x\cos\alpha+y\sin\alpha-R=0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Taking the partial derivative with respect to the parameter—

$$\frac{\partial F}{\partial\alpha}=-x\sin\alpha+y\cos\alpha=0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Equations (3) and (4) are solved simultaneously to eliminate α, as follows:

$$\begin{array}{lll} x^2\cos^2\alpha+2xy\sin\alpha\cos\alpha+y^2\sin^2\alpha=R^2 & \text{squaring} & (3) \\ x^2\sin^2\alpha-2xy\sin\alpha\cos\alpha+y^2\cos^2\alpha=0 & \text{squaring} & (4) \\ \hline x^2+y^2=R^2 & & \ldots\ldots\ldots (5) \end{array}$$

Equation (5) represents the envelope of a one parameter family of planes and it is also the well-known formula of the cylinder with radius R. This proves that the cylinder is developable.

The *helical surface,* being generated by a radial line, which turns about the Z-axis and climbs constantly in elevation an amount H per revolution, is represented by the formula

$$z=\frac{\alpha}{2\pi}H \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

It is possible to subdivide the helical surface into any number of strips, each of which is bounded by two arbitrary positions of the radial generating line. However, no individual strip will approach a plane surface, no matter how narrow the strip is taken; this follows from the fact that each strip will have a vertical edge on the Z-axis and an opposite edge at the cylinder which is inclined from horizontal at the helix angle. Thus the configuration shown in Figure 1 will not be realized. The helical surface is a ruled surface which is designated as "warped." It is not developable.

The *helical convolute* is a surface which is ex-

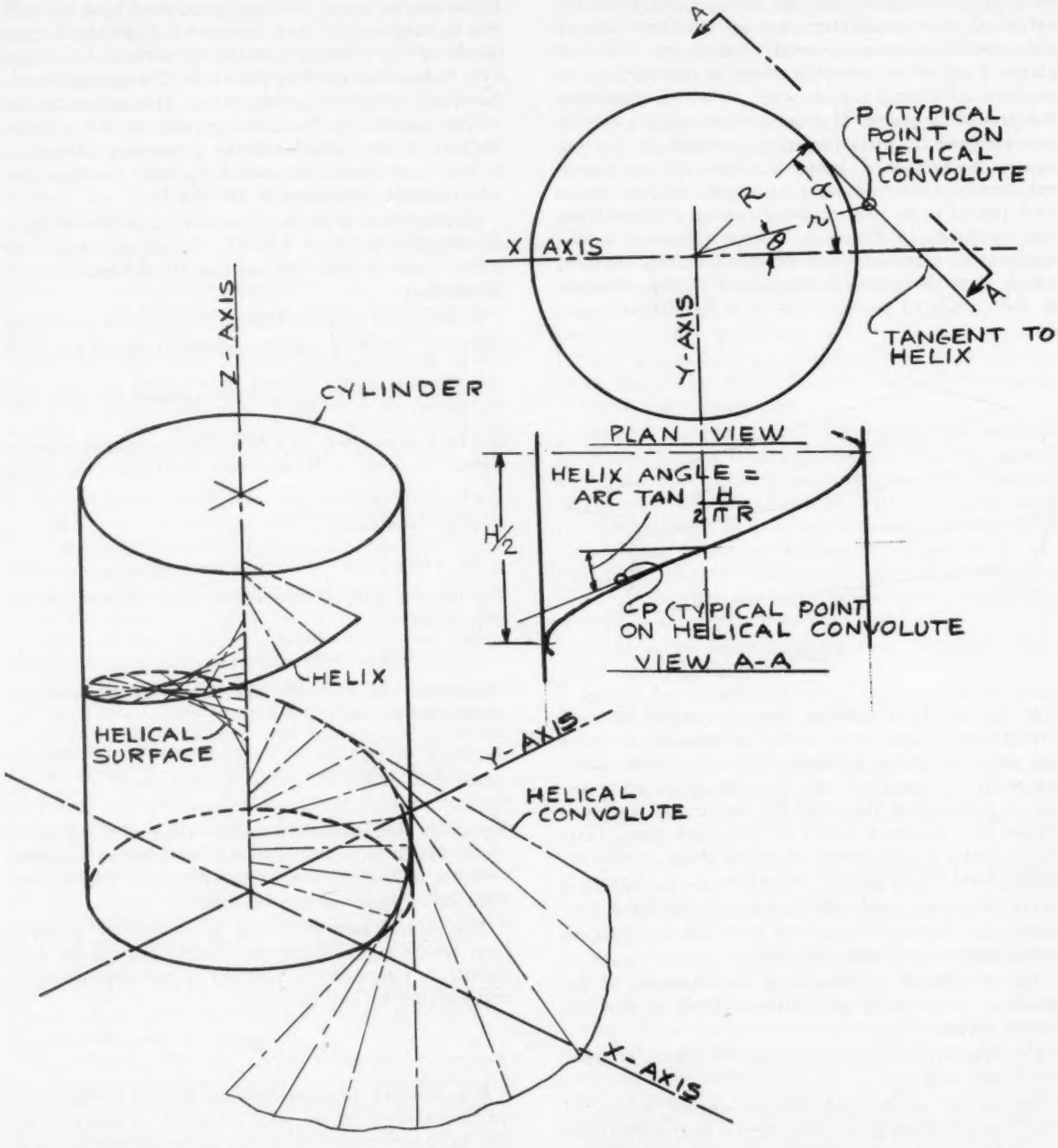

Figure 2

terior to the cylinder and is generated by the tangent line which follows the helical curve. In Figure 2 let α be an arbitrary angle of advance of the radial line R from the X-axis. The amount which R has climbed above the XY datum plane is $\frac{\alpha}{2\pi}$ H. Let P be a typical point on the tangent line, associated with coordinates θ and r; it is likewise a typical point of the surface generated by the moving tangent line. Elevation of P is less than that of the line R by an amount R tan $(\alpha-\theta)$ times the tangent of the helix angle. These relations enable one to

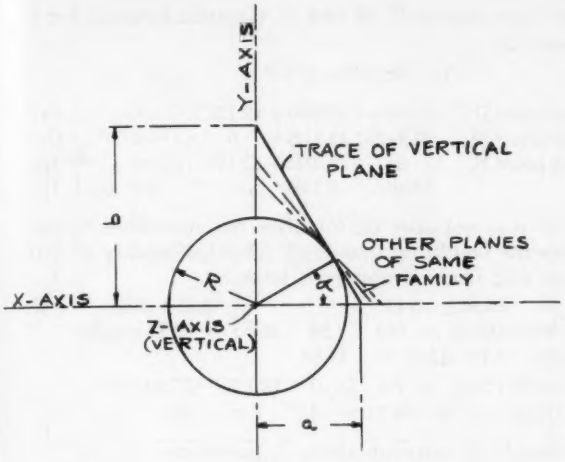

Figure 3

write down the equation of the helical convolute as follows:

$$z=\frac{\alpha}{2\pi}H-R\tan(\alpha-\theta)\,\frac{H}{2\pi R}\quad\ldots\ldots\ldots\ldots(7)$$

This may be expressed in different terms since

$$\cos(\alpha-\theta)=\frac{R}{r}\text{ and }\tan(\alpha-\theta)=\sqrt{\frac{r^2-R^2}{R}}$$

$$z=\frac{(\alpha-\theta)}{2\pi}H+\frac{\theta H}{2\pi}-\sqrt{r^2-R^2}\,\frac{H}{2\pi R}$$

$$\theta=\frac{2\pi z}{H}+\sqrt{\frac{r^2}{R^2}-1}-\text{arc cos}\,\frac{R}{r}\quad\ldots\ldots\ldots(8)$$

Consider a plane which includes a typical tangent line and the corresponding radial line of the cylinder extended, as indicated in Figure 4. Such a plane

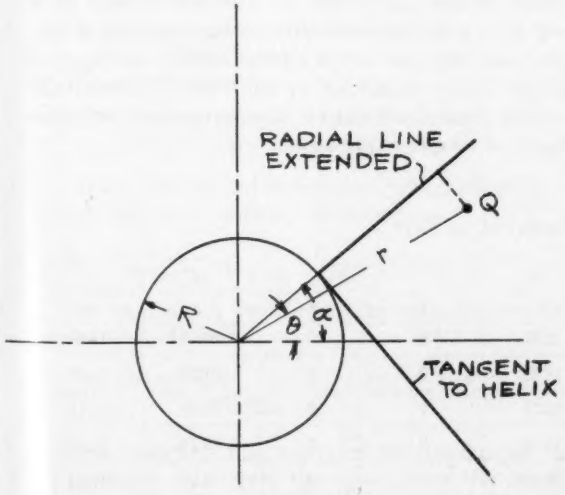

Figure 4

has a downward slope equal to that of the helix on the cylinder. The height of any point on the plane equals the height of the radial line above the X-Y datum plane, minus the height lost by the downward slope. Thus for a general point Q of the plane—

$$z=\frac{\alpha}{2\pi}H-\frac{r\sin(\alpha-\theta)}{2\pi R}H$$

or $$F=HR\alpha-Hr\sin(\alpha-\theta)-2\pi Rz=0\quad\ldots\ldots(9)$$

Considering angle α as a parameter, equation (9) represents a family of planes.

The partial derivative of equation (9) with respect to the parameter is developed as follows:

$$\frac{\partial F}{\partial\alpha}=HR-Hr\cos(\alpha-\theta)=0\quad\ldots\ldots\ldots\ldots(10)$$

To eliminate the parameter, equations (9) and (10) are solved simultaneously, as follows:

$$H^2R^2\alpha^2-4\pi HR^2z\alpha+4\pi^2R^2z^2=H^2r^2\sin^2(\alpha-\theta)\quad\ldots\ldots\text{squaring (9)}$$

$$H^2R^2=H^2r^2\cos^2(\alpha-\theta)\quad\ldots\ldots\text{squaring (10)}$$

$$H^2R^2\alpha^2-4\pi HR^2z\alpha+4\pi^2R^2z^2+H^2R^2=H^2r^2$$

$$\alpha^2-\frac{4\pi}{H}z\alpha+\frac{4\pi^2}{H^2}z^2+1-\frac{r^2}{R^2}=0$$

$$\alpha=\frac{2\pi}{H}z\pm\sqrt{\frac{r^2}{R^2}-1}\quad\ldots\ldots\ldots\ldots\ldots\ldots(11)$$

Substituting in (10):

$$HR-Hr\cos\left[\frac{2\pi}{H}z\pm\sqrt{\frac{r^2}{R^2}-1}-\theta\right]=0$$

$$\frac{2\pi}{H}z\pm\sqrt{\frac{r^2}{R^2}-1}-\theta=\text{arc cos}\,\frac{R}{r}$$

$$\theta=\frac{2\pi}{H}z\pm\sqrt{\frac{r^2}{R^2}-1}-\text{arc cos}\,\frac{R}{r}\quad\ldots\ldots\ldots\ldots\ldots(12)$$

Equation (12) represents the equation of the envelope of a one parameter family of planes. Adopting the positive sign in front of the radical, it is found that it coincides with equation (8). This proves that the helical convolute is a developable surface.

The helical convolute is just a special case covered by a general theorem which states that the moving tangent to any continuous space curve sweeps out a developable surface.

APPLICATION TO A HULL FORM

Attention is now turned to the problem of devising a formula for a developable surface which will have approximately the same shape as a given arbitrary surface. There are, of course, some practical limitations on what can be accomplished in this direction.

Somewhat akin are the limitations which affect the preparation of maps. If the whole surface of the world must be shown on one map, some very large

distortions are necessary in the transformation from the spherical surface to the plane surface. If the surface to be shown is limited to an area such as that of continental United States, the necessary amount of distortion is greatly reduced. If only a small area, such as a county is shown the distortion becomes unnoticeable.

If one tried to substitute a single developable surface for the complete half of a ship's form (i.e. the half on one side of the centerline plane), the departure from the original shape would be so great as to render the whole effort useless. However, if the ship form is divided up into a number of strips of moderate width, it may be possible to find a developable surface to fit each of the strips rather closely.

To explore this possibility, an available line plan for a ship which does not have parallel middle body is used. The chosen strip of plating is that lying between the first and second platforms, and, to hold down the magnitude of the study, the length of strip is limited to distance from Station 4 to Station 10 (amidships).

Following the method previously explained in [4], six typical points are spotted in on the half-stations and at about mid-height of the chosen strip and the coordinates of each of these points, P, are tabulated. Coordinate x is measured from the transverse plane amidships, coordinate y is measured from the centerline plane, and coordinate z from the base plane which passes through the keel.

Similarly, coordinates are tabulated for points M and N. Each M point is located by the intersection of a line m-m with the base plane, m-m being in a transverse plane and tangent to the transverse frame line at P. Each N point is located by the intersection of a line n-n with the transverse plane amidships, n-n being in a horizontal plane and tangent to the waterline at point P. Figure 5 illustrates the system of coordinates.

The above data enable the equation of the tangent plane to be calculated for each point P. To illustrate, for the point on Station 6½, the condition is imposed that the tangent plane pass through the three points P, M and N. General formula for a plane is

$$Ax+By+Cz+D=0$$

For point P $53.90A+15.08B+12.12C+D=0$ (a)
For point M $53.90A+12.71B+\ 0\ +D=0$ (b)
For point N $\ 0\ +20.21B+12.12C+D=0$ (c)
$53.90A-\ 5.13B\ =0$ (a)−(c)

Now it is not only permissible, but desirable, to impose the condition that B=1. The desirability of this step will become apparent later on.

$53.90A=5.13 \qquad A=+.095$

Substituting in (b) $53.90\ (.095)\ +12.71=-D$
$D=-5.13-12.71\ =-17.84$

Substituting in (c) $20.21+12.12C-17.84=0$
$12.12C=17.84-20.21=-2.37 \quad C=-.196$

Formula of tangent plane is therefore
$$+.095x+y-.196z-17.84=0.$$

By similar procedure, the formula for the tangent plane at each point P is calculated and the results are tabulated as follows:

TABLE 2—*Formulas for Tangent Planes*

For P on Sta 4½	$+.144x+y-.176z-21.54=0$
For P on Sta 5½	$+.119x+y-.183z-19.50=0$
For P on Sta 6½	$+.095x+y-.196z-17.84=0$
For P on Sta 7½	$+.066x+y-.216z-16.35=0$
For P on Sta 8½	$+.050x+y-.246z-15.58=0$
For P on Sta 9½	$+.026x+y-.293z-14.91=0$

The next step is to reduce the foregoing six equations to a single equation in x, y, z and a parameter ϕ. There does not appear to be any straightforward process for doing this, but it is helpful to plot the data and draw curves through the points. This is done in Figure 6, in which the quantities A, C and D are plotted above a base line marked off at the equally spaced stations.

What is really needed is a plot of A, C and D on a base of the parameter ϕ. The increments of ϕ need bear no proportionality to the spacing of stations, and thus the set of curves shown in Figure 6 can be locally expanded or contracted horizontally to bring them more closely into agreement with the graphs of simple expressions.

TABLE 1.—*Coordinates Measured in Feet*

Sta.	P			M			N		
	x	y	z	x	y	z	x	y	z
4½	84.70	11.79	14.00	84.70	9.33	0	0	24.00	14.00
5½	69.30	13.71	13.05	69.30	11.31	0	0	21.97	13.05
6½	53.90	15.08	12.12	53.90	12.71	0	0	20.21	12.12
7½	38.50	16.21	11.17	38.50	13.80	0	0	18.75	11.17
8½	23.10	16.92	10.17	23.10	14.42	0	0	18.08	10.17
9½	7.70	17.38	9.16	7.70	14.71	0	0	17.58	9.16

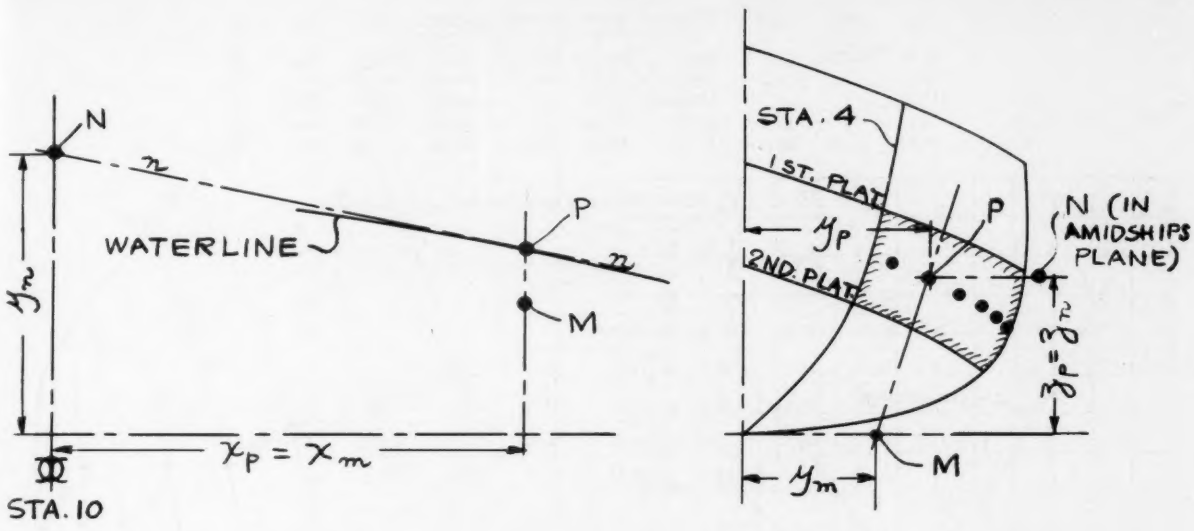

Figure 5

From inspection of Figure 6 it appears that quantity A can be approximated by a straight line, quantity C by a 3rd power equation and quantity D by a second power equation.

In Figure 7, the following graphs are shown:

$$A=.0257\ (8.4-\phi)$$
$$C=-[.171+.000274\phi^3]$$
$$D=-[14.70+.200(8.6-\phi)^2]$$

The coefficients of these equations have been so adjusted and the station spacing so adjusted that the curves fit the plotted points fairly closely. On this basis of fitting curves to plotted points, the formula for the family of tangent planes is set down as follows:

$$F=.0257(8.4-\phi)x+y-\ (.171+.000274\phi^3)z-[14.70+.200(8.6-\phi)^2]=0$$

or, by rearranging

$$F=-.000274z\phi^3-.200\phi^2-\ (.0257x-3.44)\phi-[14.70-.216x+\ .171z+14.79]+y=0 \quad \ldots\ldots (13)$$

Taking the partial derivative with respect to the parameter gives another equation

$$\frac{\partial F}{\partial \phi}=-.000822z\phi^2-.400\phi-\ (.0257x-3.44)=0 \quad \ldots\ldots (14)$$

The expression for the parameter is derived from Equation (14) as follows:

$$\phi=\frac{+.400\pm\sqrt{.160-.003288z\ \ (.0257x-3.44)}}{-.001644z} \quad \ldots\ldots (15)$$

Now inserting this value of the parameter back in equation (13) gives the equation of the developable surface. However, there is no need to write down this complicated expression. In practice, one

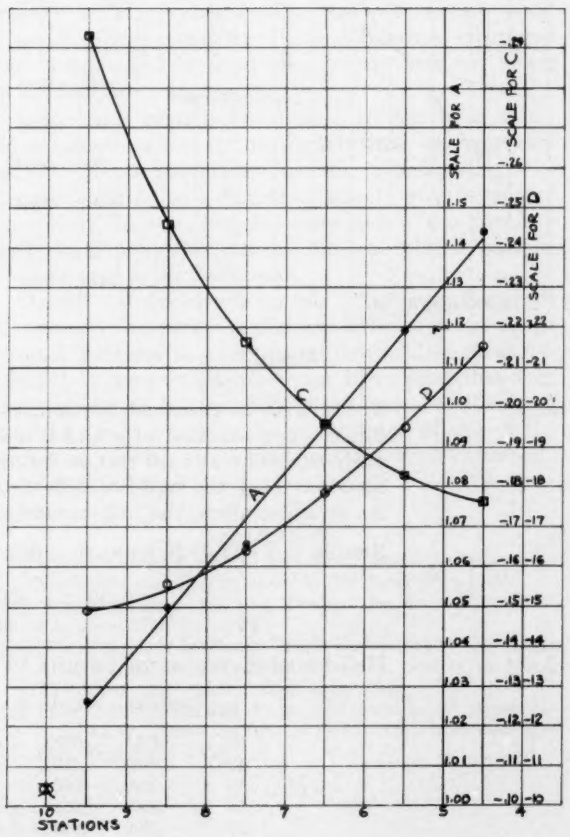

Figure 6

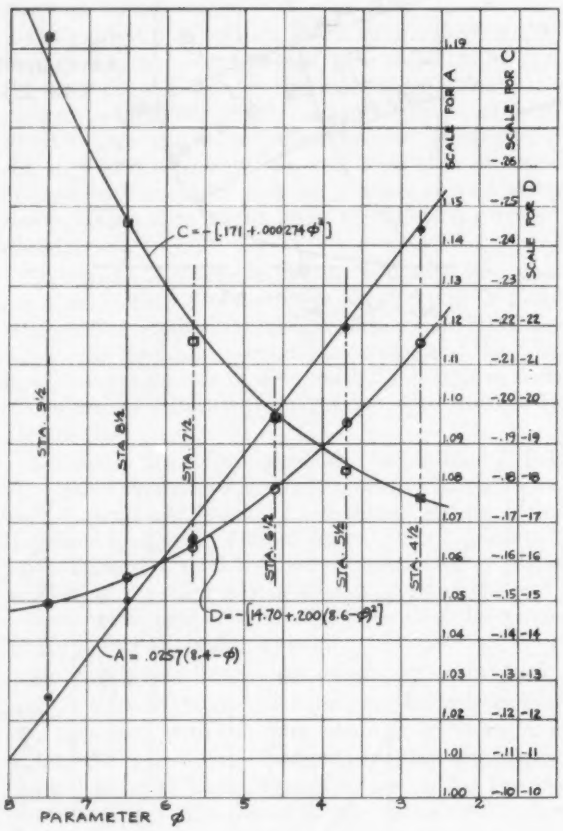

Figure 7

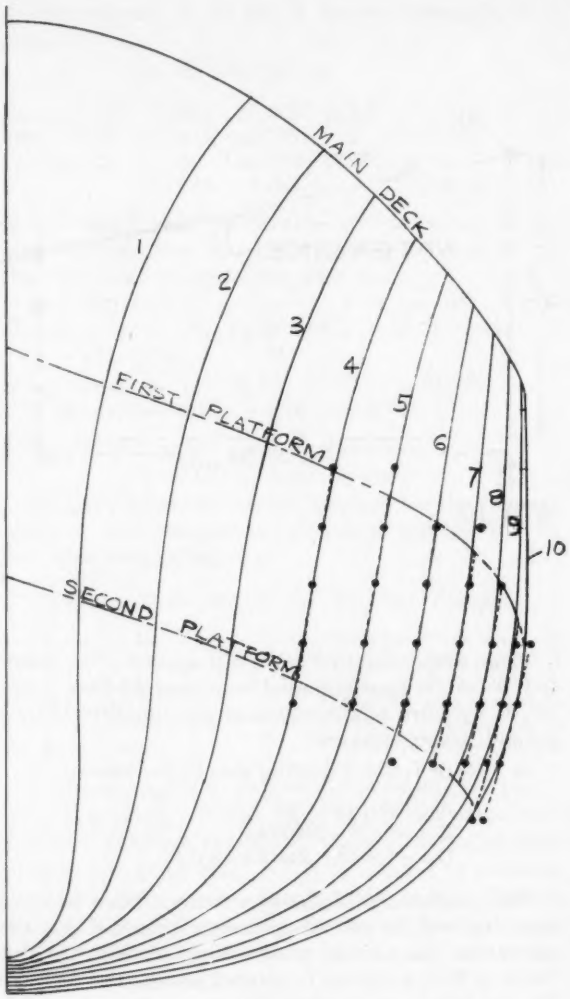

Figure 8

would wish to calculate the half-breadths at chosen stations and waterlines. Since ϕ is a function of x and z, a numerical value of ϕ can be calculated for each waterline at each station by using equation (15), then by substituting in equation (13) the half-breadth to the developable surface can be calculated. As an illustration, the half-breadths at Station 5 are calculated as follows:

Station 5, x=77.0′. Substituting this value in eq. (15) yields:

$$\phi = \frac{+.400 \pm \sqrt{.160 - .003288z \quad (-1.461)}}{-.001644z}$$

Half-breadths are wanted at the 10, 12, 14, 16 and 18′ waterlines.

z	−.001644z	−.003288z	x(−1.461)	+.160	$\sqrt{\quad}$	.400−$\sqrt{\quad}$	ϕ
10	−.0164	−.0329	+.0480	+.2080	+.456	−.056	3.41
12	−.0197	−.0395	+.0577	+.2177	+.467	−.067	3.40
14	−.0230	−.0460	+.0672	+.2272	+.477	−.077	3.35
16	−.0263	−.0526	+.0769	+.2369	+.487	−.087	3.31
18	−.0296	−.0592	+.0865	+.2465	+.495	−.096	3.24

Substituting x=77.0 in equation (13)—

$$y = +.000274z\phi^3 + .200\phi^2 - 1.461\phi + (.171z + 12.86)$$

z	ϕ^2	ϕ^3	.000274z	$x\,\phi^3$	$.200\,\phi^2$	$-1.461\,\phi$	.171z	12.86	y
10	11.63	39.65	.00274	+.109	+2.326	−4.982	+1.71	12.86	12.02
12	11.56	39.30	.00329	+.129	+2.312	−4.967	+2.05		12.38
14	11.22	37.60	.00384	+.144	+2.244	−4.894	+2.39		12.74
16	10.96	36.26	.00438	+.159	+2.191	−4.836	+2.74		13.11
18	10.50	34.01	.00493	+.168	+2.100	−4.734	+3.08	12.86	13.47

TABLE 3—*Calculated Half-Breadth (y) in Feet*

Waterline (z)	Sta. 10 (x=0)	Sta. 9 (x=15.4)	Sta. 8 (x=30.8)	Sta. 7 (x=46.2)	Sta. 6 (x=61.6)	Sta. 5 (x=77.0)	Sta. 4 (x=92.4)
18						13.47	11.27
16				16.53	14.97	13.11	10.93
14		18.27	17.35	16.11	14.58	12.74	10.57
12	18.37	17.78	16.90	15.71	14.20	12.38	10.22
10	17.80	17.28	16.45	15.30	13.82	12.02	9.87
8	17.23	16.77	15.99	14.88	13.44		
6	16.63	16.24	15.53				

The reason for assigning the value of unity to coefficient B is now clarified. It causes y, the half-breadth to come out as the dependent variable in the final equation. By choosing values for x, the distance from amidships, and for z, the height above keel (i.e the waterline) and substituting in formulas (15) and (13), the value of y results from the calculations.

Figure 8 shows the body plan of the forward end of the ship, as traced from the lines plan. In the zone between first and second platforms and between Stations 4 and 10, will be found a number of spots connected by light dotted curves. These represent the developable surface as calculated by the formula.

The rather close fit of the calculated surface to the ship's lines indicates that ship's form does not depart very much from a developable surface within the zone investigated.

PROSPECTS FOR USE OF DEVELOPABLE SURFACE

It is believed that further study of developable surfaces would lead to worth-while results. Perhaps students could investigate some aspects of the subject in their thesis work.

Large merchant ships, such as tankers, have extensive parallel middle body and the plating at the ends may be close enough to developable forms to insure no difficulty in fabrication. It is with the more curved hull forms that the application of developable surfaces looks more promising. Actual ship plates depart from developable forms by varying amounts of bulge and twist. It would be enlightening to know how large these departures can be without causing more expensive work in the shipyard.

The method of arriving at a formula for a developable surface, as outlined in the last section, could probably be systematized and otherwise improved so that it could be used in a routine manner along with computer assistance.

There are certain advantages in having a ships' form represented by formulas such as equation (13). When a particular formula is accepted, it becomes possible to compute offsets to any degree of precision desired. Furthermore, since the formula has continuous derivatives, the calculated surface will be fair in all directions.

Additional problems appear after equations are developed for strips of plating. Two adjacent strips would intersect in a chine and it would be most desirable to have exact offsets for this chine; this does not appear to be too difficult. A more challenging problem is to compute the exact shape of one of the strips of plating in its flattened out or "developed" configuration.

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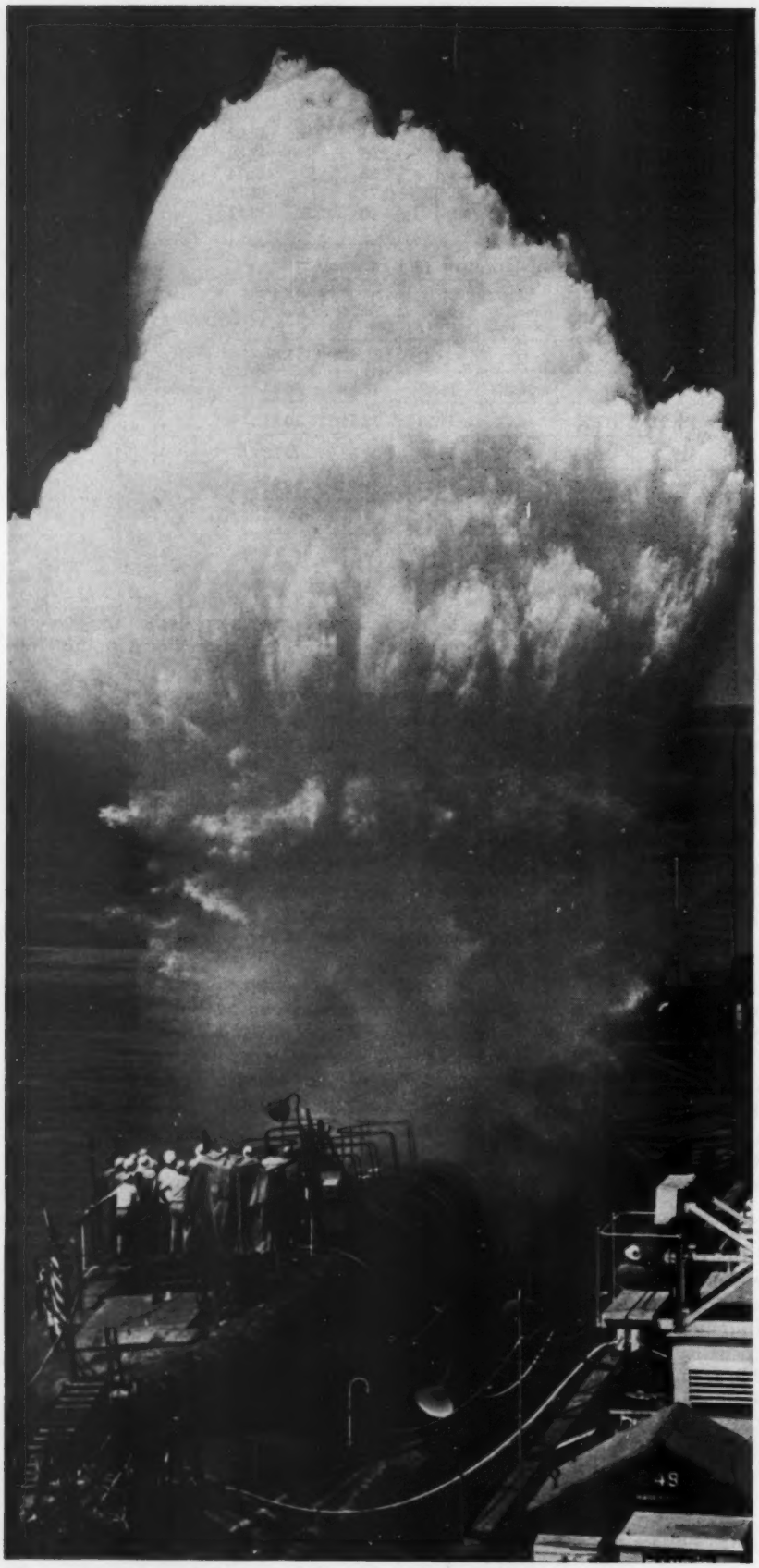

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INTRODUCTION

DURING THE YEAR 1960, two important organizations connected with shipbuilding celebrated their centenaries. The Royal Institution of Naval Architects became 100 years old in May, and in the same month the bi-centenary of Lloyd's Register of Shipping was celebrated. These were important events in another year of progress in shipbuilding and it is fitting, at the beginning of this article, to look at these two events and to take stock of the progress which has been achieved.

During the 200 years of their existence, Lloyd's Register of Shipping have contrived to develop Rules for the increasingly efficient construction of ships, and the present-day ship owes much to the experience and research of this, the first classification society. That this progress is in no way halted at the present time is evidenced by the fact that Lloyd's Register of Shipping have, during the year, published new Rules for oil-tank ships. These Rules have been developed because the increasing size of oil-tankers has involved the use of new methods for determining the scantlings of the main structural parts. A major change which will be noted is the elimination, to a large extent, of the familiar Tables which have been replaced by formulae. It is understood that a similar procedure will eventually be adopted in connection with the Rules for dry-cargo ships. Another new set of Rules issued by the Society during the year concerns the construction and classification of nuclear ships. These Rules are, of course, provisional only and are indicated as a guide in this branch of technology.

A further progressive step by the Society during the year was the reduction in the number of grades of shipbuilding steel required by the Rules from 22 to 5. This step was taken after a long period of consultation with the other major classification societies. In addition to the work of the society referred to in the foregoing, the impact of Lloyd's experience and knowledge is to be found in the research work published through other organizations, such as the British Shipbuilding Research Association.

It is very difficult to assess the influence of the Royal Institution of Naval Architects on the design and construction of ships during the years from 1860. The Institution is not a research organization and does not, therefore, engage in research projects itself. Nevertheless, it has provided a platform for the discussion of all the problems relating to ships, and it is safe to say that no major development or new idea has been introduced without being thor-

oughly discussed by the Institution. The Institution has, therefore, provided a means whereby the experts in any particular branch of the science and art of ship design and construction can get together and exchange ideas with immense benefit to the industry as a whole.

At the centenary meeting of the Institution in May of last year, which was graced by the presence of His Royal Highness The Duke of Edinburgh, two papers were read which traced the developments in ship design and construction during the past 100 years. Fittingly, one of these concerned warships and the other merchant ships. The first was read by Mr. A. J. Sims, O.B.E., R.C.N.C. [1] (now Sir Alfred Sims), and the second by Mr. J. M. Murray, M.B.E., B.Sc. [2]. Sir Alfred Sims dealt with the development of ship types and discussed the technical aspects of these and the problems brought about by changes in the materials used and the methods of construction employed. A similar field was covered for merchant ships by Mr. Murray in his paper, and he discussed the development of new types of ships during the period, such as ore-carriers and tankers, and also covered the evolution of the North Atlantic passenger liners. These two papers represent impressive research and while it may be claimed that they are largely historical, nevertheless there is much that can be learned from history in shipbuilding as in other realms.

Turning now to the activities of the research organizations, we would once again refer to the activities of the British Shipbuilding Research Association and the Ship Division of the National Physical Laboratory. These two organizations work in close association and details of the work which they have published during the year will appear in the papers referred to in later sections of this article. Here we will content ourselves by mentioning, in broad outline, the work they have in hand.

The B.S.R.A. program may be conveniently grouped under the headings of hydrodynamics, ships' structures and ship performance. Work has continued on the methodical series tests of merchant ship forms and is now being extended up to a block coefficient of 0.85. The work on trawler forms is practically complete and it is hoped to provide member firms with a series of design charts for design office use. Further work is to be undertaken on the influence of bulbous bows and special sterns for trawlers. Other matters dealt with under the heading of hydrodynamics include the determination of scientific data on rudders and investigations into the scale effect which might be experienced in the components of ship propulsion. For this purpose it is anticipated that a model some 40-ft in length will be employed and the new facilities available at Feltham make experiments on a model of this size possible.

In the structural field, B.S.R.A. are continuing the work on structural members at Glengarnock. This is concerned mainly with a comparison between swedged plating and panels stiffened with flat bars. An investigation into bracketless knee connections is also in hand.

The study of longitudinal bending continues and it has been found, in the light of stress records obtained on board ships at sea, that the stress calculated by conventional means when a ship is poised on a wave of height $1.1\sqrt{L}$ with the Smith correction ignored gives more realistic results.

The behavior of a full-scale superstructure has been tested during the year and this has shown that the superstructure in question is at least 80 per cent effective in contributing to the longitudinal strength of the ship. Work continues on the collection of vibration records on ships. The work on added virtual mass is near completion.

In the field of ship performance, B.S.R.A. teams are continuing to attend the trials of new ships and in this connection acceleration tests are to be carried out on a 50,000-ton deadweight tanker to ascertain the length of run required to attain full speed. An ultrasonic method of measuring the torsional rigidity of shafts has been developed which should lead to more accurate measurement of shaft horse power.

Hull roughness still occupies attention and, jointly with the Ship Division of the National Physical Laboratory and the National Institute of Oceanography, the problem of sea-keeping is being studied.

The Ship Division of N.P.L. are engaged on the analysis of many of the records obtained from the service performance of actual ships. Data have been obtained from O.W.S. *Weather Reporter* and from a number of voyages of the SS *Cairndhu*, and these are being analyzed with the help of the DEUCE computer. Alongside this full-scale program, a study is being made of the mechanics of wave making for simulating sea conditions in the tanks. Plans are in hand for extending to sixteen frequencies the investigations which were made originally on the combination of two frequencies in a plunger-type wave maker. Propeller design and performance calculations based on the Hill method can now be carried out on the N.P.L. DEUCE computer. An independent N.P.L. propeller design method, in which complete lifting surface corrections are made by a vortex lattice representation of the blade, has also been programmed for the ACE computer. Towing tank and water tunnel experiments, with the first models designed in this way, will be made shortly.

In the realm of cavitation, the Ship Division are carrying out tests on propellers and hydrofoils in the cavitation tunnel. The performance of the N.P.L. Standard Series of propellers has also been determined by systematic experiments in the tunnel.

The experiments to determine the effect of trim on the resistance and propulsion of coasters is now

nearly complete. Future work will be concerned with the shape of the ends and will be carried out on selected models. Other work still being pursued by the Ship Division includes ship vibration and, in particular, the problem of propeller excited vibration and the vitally important question of ship model correlation.

From the foregoing notes it will be evident that steady progress is being maintained in many important branches of naval architecture and these should lead eventually to better and more efficient ships. That this work is bearing fruit is evident form the many excellent vessels completed during the year.

STRUCTURAL STRENGTH AND WELDING

One of the most important contributions which has been made to the strength of ships during the year is to be found in a paper by Mr. I. M. Yuille, B.Sc., Ph.D., and Mr. L. B. Wilson, B.Sc. [3]. This deals with the problem of the transverse strength of ships. The paper is concerned principally with warship construction but the principles involved are capable of application to any type of craft. It will be remembered that the usual way of dealing with the transverse strength problem is to regard a transverse ring of material as being in equilibrium under water pressure and the loads imposed upon it by cargo and its own weight. The influence of the adjacent structure is neglected. The analysis of the problem is usually carried out by the strain energy method or the moment distribution method. The way in which the present investigation differs from this is that the influence of longitudinal members on the transverse strength is taken into account. What is done is to treat the portion of a ship between two bulkheads as a unit and to assume that there is no transverse distortion of the bulkheads. At intermediate positions, however, the transverse structure distorts and so do the longitudinals. In the method adopted these effects are taken account of, and a solution is obtained for the forces which act at the intersection of longitudinal and transverse members. This procedure leads to a large number of simultaneous equations and the solution of these is obtained by means of the digital computer. The results show striking differences between the calculations using the classical methods and they are in good agreement with experimental results obtained from small models. It is of interest to note that this approach to the problem could not have been solved without the use of the computer and this work is yet another example of the tremendous fields of research which are made possible by the use of such a machine.

The strength of plating is a problem which is ever of interest to the naval architect and the subject of wide plates in compression has been studied in the United States of America [4]. This work concerns the strength of flat plates with uniformly distributed loads along the longer edges and was initiated by the Hull Structure Committee of the American Society of Naval Architects and Marine Engineers. Plates of four different proportions were tested and of four different values of span thickness ratio. With all these plates, tests were carried out with simple support round the edges and with values of the edge restraint coefficient of 0.25 and 0.50. The results of the tests were put in a formula which may be studied as follows:

$$\sigma_c = 0.175 \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{a}{b} + \frac{b}{a}\right)^{1.25} \left(\frac{t}{b}\right)^{1.5} R$$

In this σ_c is the critical compressive stress, E is Young's modulus and μ is Poisson's ratio. The dimensions of the plate are a and b, a being measured in the direction parallel to the application of the load. The thickness of the plate is t, and R is the restraint coefficient. The formula derived from these experiments differs from the theoretical formulae derived for plates in that the powers 1.25 and 1.5 replace the power 2 in the theoretical results.

The structural strength of small craft is a subject about which very little is written so that a paper dealing with this problem should be welcome to designers of small vessels. Such a paper is to be found in the Transactions of the Royal Institution of Naval Architects for last year [5]. The authors are S. R. Heller, Jr., CDR, U.S.N., and Mr. N. H. Jasper, Dr.Eng., and they deal with the particular problems of planing craft. These craft differ from normal displacement ships in that not only have static loads to be considered, but the dynamic loads which cause the vessel to plane have also to be taken into account. In addition to this the impact loads to which these vessels are subjected must be considered and this is the basis for the calculation method described in the paper. The problem is, however, reduced to a static one by obtaining an equivalent static pressure which is referred to as the effective pressure. The questions of the overall strength of the hull girder and the local strength of plating are dealt with and a design procedure is laid down. The work is illustrated by a numerical example. In order to make a procedure such as this realistic, it is obviously necessary to have a large amount of experimental data, and this is given in the paper. The data cover measurements of pressure on the bottom and the accelerations experienced by the vessel under the dynamic loads. Records of such data are given and it is fully analyzed so as to provide suitable information for design purposes.

On the general problem of the longitudinal strength of ships a useful investigation has been carried out by Professor J. F. C. Conn, D.Sc., and Mr. N. S. Miller, B.Sc. [6]. This concerns the determination of the wave bending moment on ships and deals with the influence of the variation of

wave form and proportion on this quantity. The object of the calculations was to establish more clearly the effect of changes in the physical characteristics of ships and in the theoretical wave profiles used in strength calculations. The results obtained so far apply to static conditions with the ship poised in equilibrium on a wave. It is hoped later to correlate the results with experiments carried out by the British Shipbuilding Research Association with models in waves and also to relate the results to tests on ships at sea.

Some useful information on the influence of welding on the design of ships is to be found in the third annual lecture delivered to the Institute of Welding by Mr. W. G. John [7].

In this lecture, Mr. John deals with the differences which have been brought about by the changeover from the conventional riveted ship to the welded ship. These changes have, in many ways, solved the problem of fabrication and made possible tasks which would have not been contemplated with riveting. Welding has, however, brought its own problems and the author draws attention to such matters as that of brittle fracture which has been more common since the introduction of welding on a large scale. He emphasizes the need for more attention to detail design and the need for welding inspection if the dangers of failures in welded ships are to be avoided. As thoughts for the future, the author sees the need for higher strength materials, which can be welded, and also for automatic welding equipment, which can be used in congested spaces.

Although fatigue is often regarded as being rather unimportant, in so far as ships structures are concerned, we would draw attention to a symposium on the Fatigue of Welded Structures given to the Institute of Welding and recorded in the *British Welding Journal* [8]. This symposium, while not primarily concerned with ships' structures, nevertheless contains much that will be of indirect interest to the shipbuilder. The subjects cover the fatigue behavior of welded aluminum, engineering aspects of future research, fatigue testing of full-size welded structures, and fatigue of welded joints in high-strength steels. Perhaps the most useful information in this symposium, so far as the shipbuilder is concerned, is that dealing with the fatigue of aluminum alloys. Among the alloys discussed is NP5/6, a material which is used very much in welded aluminum structures in ships.

Another paper dealing with the fatigue of this particular material has also been given to the Institute of Welding during the year [9]. This records work carried out on the flexural fatigue of butt welds in ¼-in. NP5/6 plate. The results show that while there is a similarity between the curves for this material and mild steel, there is a loss of some 50 per cent of the fatigue strength of the parent metal due to the presence of a weld. This is attributed in almost equal proportions to the annealing effect in the heat-affected zone and the stress concentration created by the presence of the weld bead. Removal of the weld bead raised the fatigue strength almost up to that of the annealed parent metal. One of the satisfactory features of this particular alloy is the fact that the curves of semi range of stress against number of reversals shows a definite fatigue limit, *i.e.*, a stress at which reversal could be continued indefinitely without failure taking place.

In concluding this section on welding, we would refer readers to three papers in the *British Welding Journal* on the CO_2 process for welding steel [10]. The shielded-arc process for welding of aluminum has now become quite familiar to shipbuilders. The application of a similar process for the welding of steel is not, however, so common because of the success which has been achieved with the conventional type of electrode. In recent years, however, experiments have been made with steel using a less expensive shielding gas than argon (as is used with aluminum) and CO_2 has been chosen for this purpose. With this arrangement a bare electrode is employed. The three papers referred to discuss various aspects of this process and among other things the means by which suitable metal transfer can be obtained in position welding. One of the ways that this has been achieved is by employing the CO_2 shielded short-circuiting arc, and it has been found that with this method a sufficiently small and rapidly freezing weld pool can be obtained to permit vertical overhead welding. Whether or not this alternative process for welding steel will have any use in the shipyard is a matter which is open to question. Nevertheless, it is another way for doing a particular job and no doubt time will show if it is of any value to the shipbuilder.

RESISTANCE AND PROPULSION

Much of the work that we have to report on under this heading is concerned with model experiments and we would refer first of all to two papers read in the United States of America on the well known Series 60 models [11] [12]. The first of these papers deals with the influence of afterbody shape on the resistance, power, wake distribution and propeller excited vibratory forces. In order to carry out this investigation three models were tested. The first of these was the Series 60-0.70 block coefficient parent model and the other two were derived from this model. They both had the same sectional area curve and load waterline and the shapes of the stem and stern were the same. They differed only in the shape of the afterbody sections, which ranged from extreme U to extreme V. The models were tested with rudder and propeller. The results of the tests showed that the V stern was best on almost every account. It had the least resistance at both the deep and light displacements and, even allowing for its lower propulsive efficiency, it retained the advantage in S.H.P. at the load displacement. At the light

displacement the U form had a slight advantage on S.H.P. The V form also had the advantage in regard to alternating thrust and vibrating forces and moments. An important conclusion reached was that the distribution of wake was sensitive to section shape while variation in the block coefficient produces a change in magnitude with very little effect on the pattern. The results were obtained using a four-blade propeller and it is considered that if a five-blade propeller had been used the picture, with regard to alternating thrust and vibratory force, would have been changed entirely.

The second paper referred to [12] deals with experiments among waves on models derived from the Series 60 lines. The influence of variation in dimensions and block coefficient on the performance of a ship in waves is being investigated. In the present paper the effect of block coefficient, length-draft ratio and length-beam ratio were studied. The results of the tests were put into dimensionless form and given in diagrams for different Froude numbers. The work described in this paper was carried out in the Sea-keeping Laboratory of the Netherlands Ship Model Basin and consisted of running the models in regular waves with five different wave directions. All the tests were, however, carried out in waves of the same height. The models were fitted with propellers and variations in thrust, torque and revolutions were measured when in waves. In addition the motions of the models were recorded. As can well be imagined the results obtained from such a series of experiments were numerous and it is not, therefore, possible to draw any general conclusions. The paper does, however, give diagrams from which the influence of the dimensions and form on the various quantities measured can be ascertained and the designer is, therefore, able to see what the consequences of any variation in these quantities will be.

A paper dealing with model technique has been read during the year by Mr. R. N. Newton, of the Admiralty Experiment Works, Haslar [13]. This describes the methods which have been developed over a long period of years at Haslar for correcting for variations in the resistance properties of the water. The technique consists of running a standard model at speeds above that at which laminar flow exists and finding the mean difference from a standard value set up in 1887. This difference is applied to the results of all resistance experiments on a basis of wetted area, *i.e.*, as a correction to skin friction resistance. It has been demonstrated that by applying this correction the (C)—(K) curves for a model tested at different times can be brought nearly coincident except that for "storm" periods the correction does not entirely account for the difference between the curves at the low speed end. It would seem that while a satisfactory method has been developed for dealing with this peculiar phenomenon, the phenomenon itself remains unexplained since corrections applied to resistance measurements for temperature changes and tank currents are not sufficient to account for certain erratic changes. There would appear, therefore, to be room for further research work to clear up this apparently inexplicable result.

A most important symposium on ship trials was organized last year by the North-East Coast Institution of Engineers and Shipbuilders in conjunction with the Institution of Engineers and Shipbuilders in Scotland [14]. It is obviously not possible to deal with the details of this work in the present article. It is sufficient to say here that a wide range of problems was discussed in the eight papers which were given. These included the ship-model correlation problem, full-scale trials and their analysis, the action of propellers behind the ship and the turning and maneuvering of ships. The authors were drawn from the experts in these fields throughout Europe. The symposium as a whole represents a notable contribution to the ship trial and service performance problem, and naval architects should find an immense amount of useful information contained in the various papers.

The data available for propellers for high-speed craft must be quite sparse so that a paper on the subject delivered during the year will be welcomed by designers of this type of propeller [15]. This concerns work on a series of 12 methodically varied three-blade propellers covering pitch ratios from 1.0 to 2.0 and blade area ratios from about 0.5 to 1.0. The parent propeller of this series was based on the design for a particular high-speed craft. All the propellers were 10 in. in diameter and were tested in the Vosper Cavitation Tunnel, each at nine different cavitation numbers over a wide range of slip. The results for the parent propeller were presented in graph form showing thrust coefficient, torque coefficient and efficiency as functions of the rate of advance with cavitation number as parameter. The tests have shown that in the optimum incidence range the drag lift ratios for cavitating conditions approach the values for non-cavitating conditions at the same lift coefficient. For a given local cavitation number $\sigma_{0.7}$ the propeller with the lowest pitch ratio has the lowest drag lift ratio. It has also been shown that fully cavitating conditions (that is with cavities emanating from the leading edge of the blade and extending beyond the trailing edge) are obtained when the angle of incidence is +2.5 deg and $\sigma_{0.7} \leqq 0.08$. Under these circumstances the lift coefficient depends only on angle of incidence, slope of face and local cavitation number, but not on the basic thickness form of the blade section. This is in agreement with the theory of supercavitating hydrofoils. Compared with the drag lift ratios for non-cavitating propeller blade sections, the drag lift ratios for fully cavitating propeller blade sections are higher. The differences are small for low lift coefficient, but increase with increasing lift coeffi-

cient. It is considered that a reduction of the angle of incidence, required to obtain supercavitating conditions and hence a reduction of the drag lift ratio, may be possible by modifications to the leading edges of the blades.

Another aspect of the propeller problem has been examined in the United States of America [16]. This refers to the design of counter-rotating propellers. The design method which has been employed is based upon theory by Lerbs. The theory developed by Lerbs enables a suitable design method to be evolved for this special type of propeller. The calculations involved, however, are apparently very laborious if they are carried out by hand. The theory gives the inflow factors at each section of each propeller more accurately than previous methods have done and, therefore, gives a better control over cavitation performance. The theory results in propellers with good torque balance and higher efficiencies than single screws. The test of any theory lies, of course, in the degree of agreement with experimental results. Several sets of counter-rotating propellers have been designed on the basis of the theory put forward and so test data are available to check the theory. These show that there is very good agreement with regard to torque although at the designed condition the revolutions are 3 per cent low, but it should be noted that the design of the set of propellers from which these figures are quoted did not include the empirical correction factor for lifting surface interference. In spite of the good agreement obtained between theory and experiment, it is concluded that a rigorous lifting surface theory is required which takes account of the interference between the propellers.

Useful data on the wind resistance of the above-water form of ships has been supplied during the year in a paper by Mr. K. D. A. Shearer, D.R.T.C., and Mr. W. M. Lynn [17]. The work described in this paper was carried out in a wind tunnel. The models used were those of a tanker and two cargo ships on a 1/60th scale. These were tested in three conditions of loading with a range of relative wind of 0 to 180 deg off the bow. The models were tested in a wind gradient. In addition to these ships the results of a further series of tests on a modern passenger liner are given in the paper. These latter tests were made on 1/64th and 1/128th scale models. The larger model was tested in a wind gradient and the smaller model in both wind gradient and uniform wind conditions. For the uniform wind condition two 1/128th scale models were used to determine the wind resistance, one of these acting as a reflection model. The results obtained from these wind tunnel tests have been put in the form of two coefficients. These are:

(1) Ahead resistance coefficient $= \dfrac{\text{ahead resistance}}{\frac{1}{2}\rho/g\, V_R^2\, A_T}$

and

(2) Hughes' resistance coefficient

$$K = \frac{R\cos(\alpha-\theta)}{\rho/g\, V_R^2 (A\sin^2\theta + C\cos^2\theta)}$$

where

X = ahead resistance $= R\cos\alpha$
R = resultant force
V_R = relative wind speed in ft. per second
A_T = transverse projected area in sq. ft.
A = longitudinal projected area in sq. ft.
C = equivalent transverse area in sq. ft.
α = direction of resultant force
θ = direction of relative wind
ρ = specific weight of air, lb per cu. ft.

These coefficients are plotted to a base of relative wind direction θ. With regard to the extrapolation of these wind tunnel tests to full-size ships the results on the two models of the passenger liner on different scales confirmed the previously accepted idea that there was no scale effect in this type of resistance. This is because of the sharp corners of superstructures, which presumably tend to create a resistance proportional to the square of the velocity. It is, however, noted that certain cylindrical objects, such as masts and derrick posts, would tend to have resistance coefficients which were larger on the scale model than on the full size. Consequently, as these features are more predominant in cargo than in passenger ships then the cargo ship should show more tendency towards scale effect than the latter.

SHIP MOTIONS

Professor Edward V. Lewis and Mr. Edward Numata have made a valuable contribution to the problem of ship motions in a paper read in the United States of America [18]. The work described is mainly concerned with model tests carried out in the Davidson Laboratory. The model tested was 5 ft long and was of the well-known Series 60 type having a block coefficient of 0.60. It was tested in oblique waves of both regular and irregular patterns, the resulting motions being recorded. One of the results of the experiments was that pitching and heaving are motions which can be predicted and that the influence of rolling and yawing on these motions was small. In storm seas having a broad spectrum the head sea condition is the most serious for pitching and heaving, but quite large motions remain in short crested beam seas. It follows that irregular head seas in a narrow tank provide the best means for evaluating pitching and heaving. It is suggested that interest in oblique wave testing must center round problems of rolling and yawing and improving the control of these motions. The need for further studies, both theoretical and experimental, is apparent on the subjects of rolling and yawing in both regular and irregular oblique waves.

Data relating to the full-scale behavior of ships at

sea has been made available in the form of sea-keeping trials on three Dutch destroyers [19]. This work was sponsored by the Royal Netherlands Navy and the United States Navy. The three destroyers concerned were of different types and the object of the trials was to obtain data from which their relative sea-keeping qualities could be assessed when operating parallel in the same seaway. Motions, stresses, accelerations and slamming pressures were measured for a series of speeds and heading in two different sea conditions in order to obtain a representative picture of the behavior of the ships. The results obtained from this comprehensive set of trials are too numerous to comment on here, but the reader wishing to follow up this work will find the data summarized graphically and much of it is also available in tabular form.

DESIGN OF SHIPS

There has been a great deal of work carried out on various aspects of ship design during the year and we shall attempt to draw attention to the main publications on the subject. The first to which reference might be made is a paper read in the United States of America on general cargo ships [20]. This paper discusses the ways in which the cargo ship may be made competitive and analyzes the problems which confront the U.S. general cargo-carrying merchant marine. It is shown that the cargo ship involves large managerial and labor forces. Labor accounts for 48 to 60 per cent of the total transportation costs and about 60 to 75 per cent of the transportation of cargo by sea is accounted for by what takes place while the ship is in the dock. To improve the economic efficiency of the ship more mechanization is advocated. It is considered that, with the technology available at present, the cargo ship could be more highly mechanized and automatic and thus enabled to work with less than one-half the present crew. In like manner, automation could reduce substantially stevedoring costs.

The design of large tankers is the subject of another American paper [21]. The subject is conveniently discussed under three headings, *viz.*, hydrodynamics, longitudinal strength and machinery. A problem of considerable importance is the relationship of the hull form to vibration and it is shown that correct design of the afterbody of the ship is essential to avoid propeller excited hull vibration. Some very useful data on specific designs are included. In the realm of longitudinal strength, the large tanker has presented a problem in that the rapid increase in size has taken these vessels well beyond the limits of classification society rules. Both the empirical approach of extrapolating existing knowledge and the analytical approach to the determination of the necessary section modulus of the tanker are dealt with. Finally, the design criteria for efficient tanker machinery are considered. Chief among these are the ability to function efficiently with minimum crew and the ability to operate for extended periods at high power with the minimum of maintenance.

In recent years much interest has centered around the possibility of the submarine tanker. The literature on this subject has been further extended by a paper read in the United States of America [22]. This is the report of a study of the technical feasability of submarine tankers having a deadweight of from 20,000 to 40,000 tons and speeds of from 20 to 40 knots. In the paper will be found the general arrangement of the smallest and slowest of these ships and, at the other end of the scale, the largest and the fastest. In addition, details of many other designs are included. It is assumed throughout this design study that the vessel would be nuclear powered and it would seem inevitable that this type of machinery must be employed to have any hope of success with such a project. To give some idea of the size of these proposed vessels it may be mentioned that the 40,000-ton deadweight tanker would be over 700 ft. long and would have a circular section 102 ft. 6 in. in diameter. The power required would be 240,000 S.H.P. The authors who have made this investigation say that even if the ship were fully automated, without a crew, only about 10 per cent volume would be saved and that the only way in which the size of the ship might be reduced would be by a reduction in the size of the propulsion unit. It is not considered that such a reduction is likely to come about with the existing methods of making use of nuclear energy.

Another unusual type of ship has been dealt with by Mr. E. C. B. Corlett, M.A., Ph.D., and Mr. J. F. Leathard, B.Sc., Ph.D., in this case the liquid methane carrier [23]. The transportation of liquid methane has attracted some considerable attention in recent years, the idea being to bring the gas in liquid form from the oil fields and then pump it into gas mains to augment the natural gas supply. The particular problem involved so far as the ship is concerned is to carry the liquid at a very low temperature and to prevent it from evaporating during transit. The first of these problems is catered for by having rectangular or circular tanks within the hull of the ship. The material of construction of these tanks is important since notch sensitivity at low temperatures has to be considered. This rules out ordinary mild steel and the choice would appear to lie between aluminum alloy (which has excellent low temperature properties) or a nickel steel. According to Corlett and Leathard, there is very little to choose between these two materials from an economic point of view. Prevention of evaporation of the gas is achieved by insulating the tanks generally externally. Refrigeration machinery is not, however, provided for it has usually been considered that a certain amount of gas will be boiled off during the voyage. Apart from the special features of the tanks the methane carrier does

not differ greatly from the normal ship. The machinery is, of course, placed aft and the navigating position is slightly forward of amidships.

A unique type of submarine has been discussed at the Royal Institution of Naval Architects [24]. This is a vessel to carry out oceanographic research at a depth of 15,000 ft. Obviously a submarine which can operate at such a depth must involve very special problems not least of which is the strength of the hull. The submarine, which has been called *Aluminaut*, is constructed of aluminum. The general particulars are shown in Table I.

TABLE I—*Principal Dimensions and Other Leading Characteristics of the Aluminaut*

Length		50 ft. 8 in.
Breadth		10 ft. 0 in.
Pressure hull, length of cylinder		33 ft. 4 in.
Pressure hull, inside diameter		7 ft. 0 in.
Draft, light condition		9 ft. 6 in.
Draft, prior to dive		11 ft. 6 in.
Operating depth		15,000 ft.
Test depth		17,000 ft.
Collapse depth		21,000 ft.
Maximum submerged speed, knots		4.8
Submerged displacement at depths, lb		419,140
Ballast, lb—		
Jettisonable	7,000	
Shot	4,000	
Water	3,000	16,000
Fixed	2,000	
Payload—equipment and observers, lb		4,000
Margin, lb		5,020

The design analysis, which has been carried out on this vessel, indicates that it is possible to operate a normal submarine at the depth of 15,000 ft for the exploration of the bottom of the ocean.

Some more data has been made available on the design of oceanographic research ships in a paper read in the United States of America [25]. This paper deals with the design of surface craft and gives a great deal of detailed information on various vessels of this type. There appears to be little doubt that many vessels of this type will be built in the future, because of the tremendous expansion in the science of oceanography.

The problem of crew accommodation in ships still continues to receive attention [26], and in his latest contribution to this subject Mr. J. E. Church has dealt with the dry-cargo ship with machinery aft. He has chosen as his example a ship 460 ft length B. P., of 12,000 tons deadweight having a speed of 16 knots on a horse power of 9,000. The three principal features which have been achieved in the layout given are that every member of the ship's company is housed in the best and most comfortable position, *i.e.*, above deck amidships, every member of the ship's company is provided with separate and private single-berth cabins, and lastly, that every department is provided with its own private messroom situated close to the galley.

Turning now to the design of naval craft, a very useful survey of the history and development of the aircraft-carrier was given by Mr. J. H. C. Chapman, C.B., R.C.N.C., in a paper to the Royal Institution of Naval Architects [27]. This paper deals mainly with the carrier since 1939. It is shown how the design of carriers has been influenced very largely by the developments in aircraft. This has been particularly true since 1945, because of the rapid changes that have taken place in aircraft design. One of the main features which distinguishes the modern aircraft-carrier from earlier types is the angled flight deck and this simple device, which has greatly facilitated the handling of aircraft, is now to be found in aircraft-carriers throughout the world.

Another type of naval craft, the fast patrol boat, has been the subject of discussion during the year [28] in a paper to the Royal Institution of Naval Architects. This gives a description of the latest type of vessel of this class and general arrangements are given and various alternative types of armament are discussed. The construction of the ship is also dealt with and it is of interest to note that the frame work is of aluminum alloy while the shell is of double planking. The machinery installation is, of course, very important, and for this type of craft the Proteus gas turbine was chosen as the propelling unit.

Finally in this section on ship design, we would refer our readers to a paper on the design of submarines published in the United States of America [29]. In this paper the basic principals of the design of recent attack submarines are considered and it is shown that volume and deck area considerations are even more important than those of weight in deciding dimensions of current submarines. The vital question of choice of machinery, whether Diesel-electric or nuclear power, is dealt with from the naval architectural point of view, *i.e.*, on a weight and volume basis. Another important consideration is the space required by modern electronic equipment and also that required to fulfill the present-day standard of habitability. Stability and maneuverability are other matters discussed in this paper and the authors look into the future on the question of reducing submarine size and at the same time increasing operating depth.

GENERAL TOPICS

A symposium dealing with shipyard re-organization was held in November last under the auspices of the North-East Coast Institution of Engineers and Shipbuilders [30]. Four papers were given in this symposium and they dealt with the shipyards of Messrs. Hawthorn Leslie (Shipbuilders), Ltd., Messrs. John Readhead & Sons, Ltd., Messrs. Swan, Hunter and Wigham Richardson, Ltd., Neptune Yard, and Messrs. Swan, Hunter & Wigham Richardson, Ltd., Wallsend. All these yards have had major alterations carried out in recent years and the general trend has been to reduce the number

of building berths. This is a consequence of the great developments in welding which enables much of the construction to be done in prefabrication sheds. The developments described in this symposium should lead to more efficient ship production.

The shipbuilding industry is becoming more and more aware of the potentialities of the digital computer and we would refer to two papers in which these matters have been discussed during the year [31] [32]. The first of these deals with the application of the computer to the problems of longitudinal strength and the vibration of ships. Both of these problems involve a considerable amount of calculation and the application of the computer now means that the calculations can be carried out very rapidly. What is perhaps more important is the fact that a large number of conditions of loading can now be examined whereas if this had had to be done by the ordinary methods the amount of calculation involved would have made such investigations impossible. The second paper discusses in general terms the possibilities of the computer in ship calculations and gives one example of how it may be used in such problems as hydrostatic calculations, stability and launching. The normal calculations carried out for the launch of a ship treat the problem more or less as a static one. Naval architects will be interested, therefore, in a paper which deals with the dynamics of this important operation [33]. The paper is actually an analysis of the data obtained from the launch of a 32,000-ton deadweight tanker.

In the realm of materials some very useful information has been published in the United States of America on glass-fiber reinforced plastics [34]. This is an extensive survey of all the problems involved in using these materials which have now become quite common in small boat construction.

Another paper on materials has been contributed to the North-East Coast Institution of Engineers and Shipbuilders [35]. This concerns non-metallic materials and deals with the use of timber, insulation materials, deck coverings, ships' furnishings, polythene piping, etc.

The subject of anchors has been dealt with by Mr. H. L. Dove, M.B.E., and Mr. G. S. Ferris, B.Sc., R.C.N.C. [36]. It will be remembered that the first of these authors carried out a considerable program of model experiments on anchors some 10 years ago. The present work concerns full-scale tests on bower anchors and permanent mooring anchors developed as a result of these model tests. It is of interest to note that the final design of bower anchor now being fitted to surface warships provides 2½ to 3 times the holding pull of an Admiralty Standard stockless type and similar commercial anchors of the same weight in all types of seabed.

For those interested in sailing and the design of sailing craft, three useful papers have been published during the year [37] [38] [39]. They deal with various aspects of the sailing problem and one of the papers [39] gives the results of full-scale tank experiments.

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[31] "Longitudinal Strength and Vibration of Ships by Electronic Computer," by Mr. R. H. Judd, B.Sc.; Transactions of the North-East Coast Institution of Engineers and Shipbuilders.

[32] "Some Uses of Computers in Shipbuilding," by Mr. N. L. Lawrie, B.A.; Transactions of the Institution of Engineers and Shipbuilders in Scotland.

[33] "The Dynamics of Launching," by Mr. R. C. Grey, B.A.; Transactions of the North-East Coast Institution of Engineers and Shipbuilders.

[34] "Fibreglass Reinforced Plastics for Marine Structures," by Mr. T. M. Buermann and Mr. R. J. Della Rocca; Transactions of the American Society of Naval Architects and Marine Engineers.

[35] "Non-metallic Materials used in Shipbuilding," by Mr. L. W. A. Rayner, B.A., R.C.N.C.; Transactions of the North-East Coast Institution of Engineers and Shipbuilders.

[36] "Development of Anchors," by Mr. H. L. Dove, M.B.E., and Mr. G. S. Ferris, B.Sc., R.C.N.C.; Transactions of the Royal Institution of Naval Architects.

[37] "The Behaviour of the Sailing Yacht," by Mr. H. M. Barkla, M.A., B.Sc.; Transactions of the Royal Institution of Naval Architects.

[38] "The Geometry of Sailing to Windward," by Mr. T. Tanner, A.C.G.I.; Transactions of the Royal Institution of Naval Architects.

[39] "Full-scale Tests of an International 10 sq. Metre Class Canoe," by Mr. T. Tanner, A.C.G.I.; Transactions of the Royal Institution of Naval Architects.

Two seagoing small gas turbines built by the Garrett Corporation's AiResearch Manufacturing Division, Phoenix, Ariz., will start and supply electricity for a new 104-ft-long hydrofoil boat capable of 80 knots on the open seas. It is being built for the U. S. Maritime Administration by Grumman Aircraft's Dynamic Developments.

Scheduled for launching early next spring, the 80-ton, all-aluminum hydrofoil will use two AiResearch GTCP 85-91 turbines equipped with special, light aluminum housings. These units will pneumatically start the aircraft-type turbine prime mover which skims the craft through the water on two sets of foils.

Once their task of spinning the main jet power plant to life is completed, the turbines will generate all the electrical power needed to operate the boat.

Based on Grumman's experience in building amphibious aircraft, the boat relies extensively on aircraft-type construction. In operation, a set of foils in the water just forward of the craft's center of gravity will "fly" the boat hull above the water. Another set of smaller water-foils well aft provide stability and high-speed maneuverability.

—from MECHANICAL ENGINEERING
February 1961

WILLIAM E. BLEWETT, JR.

A HISTORY OF THE NEWPORT NEWS SHIPBUILDING AND DRY DOCK COMPANY

ACKNOWLEDGMENT

To commemorate the 75th anniversary of the Newport News Shipbuilding and Dry Dock Co., the company's president, Mr. William E. Blewett, Jr., delivered an address at a Newcomen Society dinner. With minor modifications, this address was as follows.

THE DELIVERY NEXT YEAR of the nuclear-powered aircraft carrier *Enterprise,* the world's largest ship, will climax three-quarters of a century of shipbuilding at Newport News. This 1,100-foot ship would probably be beyond the comprehension of the Newport News shipbuilder of 1890, who built the first hull—a 90-foot tug—in that year. This first hull is still in active service in the waters of Hampton Roads, and despite the difference in size, the shipbuilders at Newport News feel that both vessels have one characteristic in common—the quality which is built into every ship constructed at Newport News.

The Newport News Shipbuilding and Dry Dock Company was established as the Chesapeake Dry Dock and Construction Company in 1886 by Collis P. Huntington. It can be said, however, that it did not start as a shipbuilding and ship repair yard operating on its own merits until 1900, when upon Huntington's death a representative of his heirs advised the president of the Yard that "we no longer have Mr. Huntington's bank account to fall back upon to help us out of tight places, and the Yard must, from this time on, take care of itself. I see no good reason why it should not, especially as other yards not as well arranged for business nor as thoroughly equipped with modern appliances, earn dividends on their capital."

Up until 1900, the Shipyard had been dependent upon Huntington to furnish funds to cover contract losses or for plant improvements and additions. An indication of the amount advanced by him was recorded in 1903, at which time $5,000,000 in bonds and up to $6,000,000 in preferred stock of the Company were issued in the settlement of his estate.

Upon the completion of the Central Pacific Railway in 1869, Huntington envisioned a single transcontinental railway system. To this end, he aided in organizing the Southern Pacific Railway and acquired control of the Chesapeake and Ohio Railway to form the basis of an eastern extension. When the plan broke down at the western end, Huntington was left with the then unprofitable Chesapeake and Ohio, which had its eastern terminus at Newport

Newport News SB&DD Co. Photograph

In 1892, the Newport News plant extended only four city blocks, from the gate of the city's 37th Street (foreground) north to 41st.

News. The city fronts on one of the finest deep water harbors in the world. To take advantage of this and to stimulate port activities with resulting outlets for his cheap coal, Huntington decided to establish a shipyard to attract more vessels to Newport News. In commenting on the selection of the site for the Yard, Huntington said sometime later, "It was my original intention to start a shipyard plant in the best location in the world, and I have succeeded in my purpose. It is right at the gateway to the sea. There is never any ice in winter, and it is never so cold but you can hammer metal out of doors."

The official opening of the first dry dock was held in April 1889, and shortly thereafter the decision was made to add shipbuilding on a large scale to the repair work. The first work comparable to shipbuilding was the re-building of the former British Steamer *Kimberley*. This job—in excess of $300,000—required work in practically all shipbuilding trades and furnished the start of the organization and training of a shipbuilding force. Our first two shipbuilding contracts were for two tugs in 1890; the loss exceeded 31 per cent of the contract price. There followed four contracts for merchant vessels which were fairly profitable.

The Yard bid on its first Naval contracts in 1893 for three gunboats. In spite of protest on the lack of experience of the new yard, the contracts were awarded to the Shipyard on the basis of its low bid. Huntington wrote as follows: "The price seems very low and more particularly so, as you know my feeling is that every ship we build there should be first-class in quality in every respect, whether we make or lose on her. In fact, I think the Shipyard in the end will make more money to do first-class work than to get ever so little below that high standard. I think we have got the best Shipyard plant in the world. What I want to do is to have for it the reputation of building the best ships. So do not make any calculations on scrimping the works on any of their parts." This was one of many similar statements made by Huntington.

There were heavy losses on most of the early contracts that certainly would have put the new Shipyard out of business had it not been for the steady flow of money from Huntington. The first Naval contract, the Gunboat *Nashville,* was a loss of $111,000, or 21 per cent. The next two Gunboat contracts of 1897, Hulls 8 and 9, were even worse with a loss of $287,000, or 28 per cent. The big blow which would have caused many persons to abandon the shipbuilding business was the deficit of $536,000—a loss of almost 52 per cent—on Hull 15, the passenger liner *La Grande Duchesse,* which was built in 1895. Total profits on seventeen vessels built during the period from 1891 to 1896 amounted to only $105,000, while the losses totaled over a million dollars.

After Huntington's death in 1900—whether as a result of the statement that the Shipyard was on its own or of the experience gained in building the first series of contracts—the Yard did begin to build ships at a profit. The famous old battleships *Kearsarge, Kentucky, Illinois* and *Missouri* were built profitably and were among the seven Newport News-built ships of the Great White Fleet that sailed around the world in 1907, as a demonstration of the power of the United States. How well the Yard had established its reputation with the United States Navy was brought out in a statement by Admiral Dewey in 1903, upon the occasion of an inspection of the battleship *Missouri.* He congratulated the Yard on all the ships built for the Navy and said that everybody in Washington—from the President on down—looked upon the Newport

Newport News SB&DD Co. Photograph

Today, the 1¼ mile waterfront of the 240-acre Newport News plant faces 22 city blocks, south to 33rd and north to 55th Streets.

News Yard almost exclusively for building warships. He also said that, if the *Missouri* had been at Manila, he could have taken care of the Spanish fleet without further assistance.

In 1903, two of the Country's leading shipyards—Cramp Shipbuilding Company and the United States Shipbuilding Company, which was later acquired by the Bethlehem Steel Company—were reported to be in financial difficulty, but the Newport News Yard at that time had six ships under construction, including three battleships and a cruiser. A few years before, one of the officials of the Yard had remarked that the entrance of the Company into the field of Naval construction had reduced the price of battleships a quarter of a million dollars. This fact probably accounted for the favorable workload at Newport News, as compared with the Country's other shipyards at that time.

For the next ten years—from 1904 to the start of war in Europe in 1914—the Shipyard continued to expand and became less dependent on Naval construction in its operation. Contracts were received during this period for fifteen Naval vessels, while other construction, including ferries, tankers, freighters and passenger vessels, consisted of a total of eighty-four contracts. The Yard became so busy during this period that there was a shortage of labor. One of the solutions which were tried was to import a Slav colony from New York. But this arrangement for the use of immigrant labor proved unsatisfactory, and it was necessary to procure employees within the state of Virginia and from our neighboring state of North Carolina, just as we do at present.

We hear much today about a 35-hour work week; and the 40-hour work week, of course, is in general

use. At the Newport News Shipyard—up until 1913—a ten-hour day and a 60-hour work week were in effect. During that year the work week was reduced to 50 hours and rates of pay were adjusted to yield the same scale as earned for 60 hours. This was brought about by the fact that many of the departments could not work a ten-hour day the year round because of early darkness during the winter months. It might be said, however, that this adjustment in pay rates started a trend in the Yard which has extended with some interruptions to the present day.

Following the developments of the war in Europe, the Government realized the great need for ships, and in August 1916 announced a three-year Naval program. Authorized by Congress were ten battleships, six battle cruisers, ten scout cruisers, fifty destroyers and seventy-eight other vessels. The Newport News Yard received contracts for two battleships—the *Maryland* and *West Virginia*, and shortly after war was declared on April 6, 1917, an additional award was made for two battle cruisers—the *Constellation* and *Ranger*.

An extensive program of plant expansion, resulting in a final expenditure of about five million dollars, was started. Included among other new facilities were two shipways for the battle cruisers. Events of the war resulted in a greater need for destroyers and other types of ships, so work was deferred on the battle cruisers and battleships.

At the time of the outbreak of war, approximately 20 per cent of the total tonnage of the U.S. Navy had been constructed at Newport News. During the emergency, operations in the plant were stepped up on an unprecedented scale. Despite the increasing tempo of enlistments by employees into military service, the Shipyard roll had increased to over 7,500 by the time of the actual declaration of war; another 2,000 were added by May of 1917 and rapidly increased to a maximum of 12,500. Twenty-five destroyers and twelve other vessels were produced during the eighteen-month period of the war.

Even prior to the start of the war, housing for employees had been acute. During the war they lived in temporary barracks, tents or other accommodations. An entire village was constructed for five hundred families, and apartments and individual houses were constructed for hundreds of others.

Shipyard employees had an additional desire to win the war because of the loss of the President of the Company, A. L. Hopkins, in the sinking of the liner *Lusitania* by a German submarine. Hopkins was succeeded by H. L. Ferguson, who was to remain President of the Yard until 1946. C. B. Orcutt, President of the Company from 1889 until his death in 1911, was succeeded by W. A. Post, who lived only a few years after assuming office. J. B. Woodward, Jr., was my predecessor in the Presidency.

The recession of the early 1920's was a period of hard times throughout the Country, as most firms found it difficult to readjust to a peacetime economy after the war. For the Shipyard a combination of circumstances, including the unprecedented ten-year "Naval Shipbuilding Holiday," made the years of 1921 and 1922 the most difficult in our history. Work was stopped on contracts worth seventy million dollars, and the Shipyard's enrollment dropped from 10,000 to 4,000 within a period of one year.

Soon after the Armistice, the Shipyard resumed work on the Naval vessels whose construction had been deferred during the war. These included two battleships, two battle cruisers and a third battleship contract awarded in 1919. The fixed-price contracts for these ships had been signed prior to the beginning of the war; but, because there had been a considerable increase in material and labor rates as a result of the war, the terms of the contracts were changed to cost plus 10 per cent profit. This procedure was the basis of considerable discussion in a Senate investigation of the Nye Committee, which I will mention later on.

The Disarmament Treaty was signed in February 1922, and all Naval work was ordered suspended in the Newport News Yard, resulting in the reduction of the work force to about two thousand men.

The Naval program of 1916, authorizing construction of the six battle cruisers which included the *Constellation* and *Ranger*, was sacrificed to establish capital ship parity with Great Britain. The same parity was established by the Disarmament Conference for the airplane-carrying craft of the two nations, each being allowed a total tonnage for such vessels. As a result of these agreements, the United States scrapped four of her six ships, including the two under construction at Newport News. Two ships were retained for conversion into aircraft carriers. These were the *Lexington* and *Saratoga;* one was built at New York Shipbuilding and the other was constructed by the Bethlehem Steel Company.

The treaty permitted the United States to complete one battleship under construction, either the *West Virginia* at Newport News or the *Washington* at New York Shipbuilding. The contract for the second battleship at Newport News was cancelled; another—the *Maryland*—had been delivered before the treaty was signed. The *West Virginia* was so much further advanced than the *Washington* that it was a foregone conclusion that she would be the one completed. However, quite by accident it was discovered that the *Washington* was to be selected for completion. The President of the Yard went to the White House the next day and learned from the President's secretary that a cabinet meeting was to be held that morning to determine which ship would be completed. He was unable to see the President, so, as the Company's representative, he wrote him a note requesting him not to make a decision until a survey had been made. This was

Newport News SB&DD Co. Photograph

The carrier *Essex*, delivered in 1942, was the first of 8 carriers of this Newport News-designed class built by the Yard during World War II. In this same period 5 other shipyards produced only 9 *Essex* Class carriers.

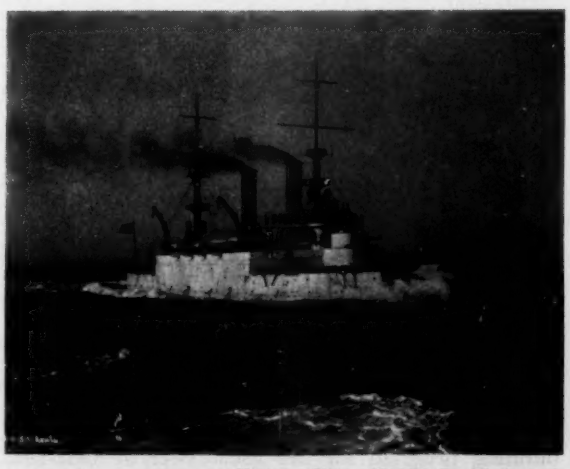
agreed to, and the survey determined that it would cost $1,500,000 more to complete the *Washington* than the *West Virginia*. The *West Virginia* was the last capital ship built until the end of the ten-year "Naval Holiday."

There was an interesting development for the art world in connection with the battleships *Maryland* and *West Virginia*. Because of the hardship and financial losses resulting from contract cancellations and Government-requested delays in construction of the ships, the Company requested that the Government make an adjustment in the contract price for stand-by time and rental of facilities. This the Government agreed to do. Henry Huntington had married Mrs. Collis Huntington and was Chairman of the Board of the Shipyard at the time. When Huntington was advised of the good news and how badly the funds were needed, he requested the Company to issue a check for $500,000, the greater part of the contract adjustment amount, to be used for the purchase of the famous painting, "The Blue Boy," by Gainsborough. The painting is still on display in the Huntington Museum in California.

With no ships to build the Shipyard embarked on a program of diversification in many lines of work. Railroad cars, traffic signal lights, disc wheels and a variety of other products were manufactured. This period also marked the entry of the Shipyard into the water power equipment field, and this is the only one of the diversified fields of the 1920's that was continued in volume beyond the depression period. The Company has become one of the largest manufacturers of this equipment and has built hydraulic turbines for such famous installations as the Grand Coulee, Chief Joseph and Hoover Dams; and currently we are furnishing six of the turbines for the Niagara Development in New York State. However, I might say in passing that our participation in this field is now threatened by a Government ruling which permits foreign companies to compete with only a 6 per cent differential in favor of a domestic bidder.

Even while the Yard was successfully developing other work for the plant, shipbuilding remained its primary function. Bids were submitted for every possible contract, but the first ships of any size built during this period were two passenger-cargo vessels for which contracts were received in July 1922. Prior to that, however, the Yard in February 1922 had submitted the low bid of about five and one-half million dollars for the reconditioning of the giant 950-foot liner *Leviathan*, acquired from Germany during the war. This was the largest job of its type in history. It furnished work for almost 2,000 men for a period of a year. Not only did it greatly aid the economy of the city, but it also helped keep our shipbuilding organization together. Upon completion of the job, the Yard's President said, "I doubt if there has even been a job so that taxed our utmost resources, patience and skill." The loss on the contract was about one and one-quarter million dollars, and it is said that, when the President of the Yard left for New York to tell Henry Huntington of the loss, he had a letter of resignation in his pocket. When Huntington was told of the loss, he is reported to have said: "My wife owns most of the stock in the Shipyard, and she has not been feeling too well recently, so maybe we should say no more about it."

From July 1921 to January 1927 during the ten-year "Naval Holiday," the Yard built nine yachts, fourteen passenger-cargo ships, two tankers, and twenty-four other smaller vessels. Many of these ships, including the nine yachts, were built at a loss. In July 1927, the Shipyard received contracts for



Newport News SB&DD Co. Photograph

The 375-foot *Kentucky* was the second of 14 battleships eventually built by Newport News when she left the Yard in 1900.

Newport News SB&DD Co. Photograph

The Battleship *Maryland*, built in 1921, gained renown in the Battle of Leyte Gulf during World War II. "Old Mary" was in the line of heavy battleships which "crossed the T" of the enemy fleet in the historic naval engagement at Surigao Strait.

the cruisers *Houston* and *Augusta*, the first Naval vessels to be built following the "Holiday."

At one time or another probably the majority of companies with substantial volumes of Government business have been involved in some manner of Federal investigations, and the Newport News Shipyard has been no exception. We were a participant in the so-called Shortridge Hearings in 1926, concerning lobbying activities in the failure of the Tri-Power Naval Conference at Geneva, Switzerland, and with other Naval and shipbuilding legislation. The three major East Coast shipyards had retained the services of W. B. Shearer in connection with these Government matters, and a Naval Affairs Subcommittee, headed by Senator Shortridge, did not look kindly upon the participation of the shipyards in these affairs.

In 1935, also, the Company was involved in an investigation of the munitions industry by a special Senate committee headed by Gerald P. Nye. This investigation had as its objective the elimination of war through the curtailment of profits by the munitions industry. The hearings disclosed some rather substantial profits on Naval work, not only by the Newport News Yard but others as well. The direct result of these hearings was the passage of the Vinson-Trammell Act which restricted profits to 10 per cent of the contract price.

During the year 1929, the Yard received substantial contracts for construction of four large passenger-cargo vessels, *Morro Castle, Oriente, President Hoover* and *President Coolidge*. The Naval building program for the fiscal year of 1932-1933 was drastically reduced in the administration's effort to balance the budget. This, together with the general depression of the period, affected the operations of the Yard to the point that for a period of nine months in 1933 it was necessary to reduce work to a four-day week. The depression period was utilized by management to regroup its forces and methods and to embark on a training program that was to prove an asset in the production of ships in the Second World War.

During the twelve-year period from 1929 to 1941, a total of forty-seven ships were built. Two events of importance during the period were the construction of the passenger liner *America*, the largest ship built in this Country at that time, and the *Ranger*, the first vessel designed and built from the keel up as an aircraft carrier. The United States Maritime Commission had been created and immediately launched a ten-year program of building fifty ships each year. The *America* was the first contract under this program. Unfortunately for the shipbuilding industry, these programs for the construction of a given number of ships each year seldom materialize, primarily because Congress does not appropriate the necessary funds to implement the programs.

The contract for the aircraft carrier *Ranger* marked the entry of the Company into the construction of a class of vessel that was to become an important part of its Naval ship production even to the present day. Under the National Recovery Act of 1933, the Shipyard received contracts for the carriers *Yorktown* and *Enterprise*, and the carrier *Hornet* was awarded to the Yard in 1938. In all, a total of eighteen aircraft carriers have been built by the Company, and with but one exception it has been the leading yard in designing every class of carrier built by the Navy.

Shortly after the death of Collis Huntington, Mrs. Huntington stated that she had been urged to sell the Shipyard but that she would not think of doing so for sentimental reasons and that from her observation of the condition of the plant, she thought the money could not be invested to better advantage. Mrs. Huntington died in 1924 and left the majority ownership in the Company to her son, Archer Huntington. He retained ownership until 1940, when the Company was sold for $19,500,000, and for the first time the stock became available to the public through a listing on the New York Stock Exchange.

When Pearl Harbor was attacked on December 7, 1941, the Shipyard was already heavily engaged in Naval construction. With a completely equipped and integrated plant and a skilled engineering and construction staff, it was well prepared to devote its full efforts to the delivery of forty-six ships to the Navy during the actual war period. Altogether, a total of one hundred and eighty-five Newport News-built ships participated in the Second World War.

During the war the Shipyard's efforts were devoted mainly to the production of eight *Essex* Class aircraft carriers. Between the delivery of the *Essex*

in December 1942, and the *Boxer* in April 1945, Newport News delivered a carrier every fifteen months. Five shipyards built seventeen of the Newport News-designed *Essex* Class carriers during the war period. Eight of these were built at Newport News. No other shipyard approached this record. *Ranger, Enterprise, Essex, Yorktown, Intrepid, Hornet, Franklin, Ticonderoga* and *Randolph* were some of the famous Newport News-built carriers that played such an important part in the battle of the Pacific.

At one period during the war top priority in Naval ship construction was given to the building of urgently needed landing ship tank vessels. These 327-foot ships were mass-produced on both coasts, and Newport News was next to the last to begin construction on eighteen of these vessels. We were first to make delivery of a completed vessel, and of the first sixteen delivered, ten were built by Newport News. These ships were built six at a time in one of our large graving docks, and the Newport News planning for mass assembly and construction was used as a guide by many of the shipyards in building a total of more than eleven hundred of these vessels.

The Newport News Shipyard was called upon for an emergency pioneering project in April 1941, in connection with the design and conversion of cargo vessels into escort aircraft carriers, commonly known as "baby flattops." German submarines were sinking a great number of the merchant ships carrying materials to England, and it is said that President Franklin D. Roosevelt originated the idea of protecting the ships with small escort carriers. Because of our previous experience in the design of aircraft carriers, we were assigned the task of originating a prototype carrier in the shortest possible time. On the fifteenth day after the drawings had been started, the Yard began to prefabricate materials in anticipation of the arrival of the first ship to be converted. On June 2, 1941, only seventy-seven days after her arrival in the plant, the ship sailed as a combat aircraft carrier under her new name, *Long Island*. A total of five of these vessels were converted at Newport News and hundreds were converted or built elsewhere to play an important role during the war in all theaters of operation.

Meanwhile, our subsidiary at Wilmington, North Carolina, delivered a total of two hundred and forty-three merchant ships, aggregating 2,600,000 deadweight tons and measuring twenty-one miles in the United States' "bridge of ships" for the war effort. The peak wartime employment at Newport News was reached in April 1943, when over 31,000 persons were on the payroll; the subsidiary shipyard's maximum enrollment was almost 21,000.

The success of the *Essex* Class carriers in the Second World War led to new classes with improvements and even greater size to accommodate the heavier, longer-range aircraft. The *Essex* Class, of which the *Leyte* (1946) was the last to be built at Newport News, had been lengthened to 888 feet. The 933-foot *Midway*, a new class, was the largest warship ever built when she was delivered in 1945. Her sister ship, *Coral Sea*, followed in 1947. Through the 1950's to the present, our Nation has drawn on Newport News' experience in the design and construction of the 1,039-foot *Forrestal* which was delivered in 1955, and the 1,046-foot *Ranger* delivered in 1957. The 1,100-foot *Enterprise* will become operational next year.

The end of the Second World War followed the usual pattern of peaks and valleys in the curve of shipbuilding activities with the resulting sharp decline in enrollment from the wartime high of thirty-one thousand to eleven thousand. Three light cruisers, a heavy cruiser and an aircraft carrier were cancelled; however, we retained contracts to complete the two aircraft carriers mentioned above—*Midway* and *Coral Sea*—which were well along in construction, and the contract to build the heavy cruiser *Newport News*. Two carriers of the *Midway* Class had previously been cancelled in the early part of 1945.

As usual, there was a dearth of new shipbuilding following the war. A contract was received in July 1945 for three fruit ships, but during the next eighteen months the only new construction work received was for two tugs. The Shipyard, however, managed to maintain a fair level of production, mainly by the procurement of a number of large ship conversion projects, including the passenger liner *America*, which had been in use as a troop transport.

One of the most interesting operations undertaken by the Company to furnish work for the plant at this difficult time was the purchase of five escort carriers similar to the ones converted during the war. They were re-converted to their peacetime status and then re-sold by the Company to ship operators.

After this period of adjustment the Shipyard received contracts for eleven tankers during the first six months of 1948. This was the beginning of a trend of building larger and faster tankers for reduction of operating costs, and the thirty-one additional tanker contracts received from that period to the present has furnished a substantial portion of our new construction volume. The Suez Canal crisis of a few years ago accelerated this tanker program.

An interesting development of 1949 was the controversy between the Navy and Air Force, regarding the fighting effectiveness of aircraft carriers. This eventually led to the cancellation of the 1,090-foot carrier which Newport News had under contract and the subsequent resignation of Secretary of the Navy John Sullivan, who opposed the cancellation decision.

In merchant ship construction the early 1950's

Newport News SB&DD Co. Photograph

The world's largest ship and its first nuclear-powered aircraft carrier, USS *Enterprise*, will be delivered to the Navy later this year.

were highlighted by our building of the 990-foot passenger liner *United States*. She is the largest passenger ship ever built in this Country and the fastest ship of her size afloat. This luxury liner holds the Blue Riband for the fastest crossing of the Atlantic in both directions. She averaged almost 42 land miles per hour on a full day's run.

The tanker-building program, the passenger liners *Santa Rosa* and *Santa Paula*, together with the three large aircraft carriers previously mentioned and the other merchant ship work received since 1948, has kept the Shipyard at its highest level of peacetime production in its seventy-four year history.

The advantage of any company in the shipbuilding business depends greatly upon its facilities. From the beginning of its shipbuilding operations, Newport News' plant facilities have been outstanding among the shipyards of the world. In 1890, equipment included various types of traveling cranes, steel fabrication equipment and a graving dock built to accommodate the largest ships of the time. Over the years our facilities have been expanded to meet the increasing demands of the industry. When the new President of the Company assumed office in 1915, he stated to Archer Huntington his belief that profits were generated by a modern, well equipped plant. Huntington agreed and, as Chairman of the Board, urged the President to see that the Yard had the best facilities available.

This has been the policy throughout the years, and some indication of its fulfillment can be realized by the fact that a total of forty-four million dollars was expended for plant improvements between 1946 and 1959. The plant now extends for a mile and one-quarter along the deep water of the James River, covers one hundred and forty-four acres and includes graving docks and piers built to accommodate the largest ships in the world. The Newport News Shipyard is the most fully integrated shipbuilding organization in existence and includes—in addition to the usual facilities—a foundry, pattern shop, paint factory, forge shop, galvanizing plant, electroplating shop and many others. We make every effort to furnish every part of a ship under construction that we can manufacture or build more cheaply than it can be bought from others.

The design and construction of a nuclear aircraft carrier such as the *Enterprise* is one of the most complex engineering feats of man. It is a fortified city of 4,600, complete with employment in trades and professions, living quarters, facilities for recreation, health and sanitation, unexcelled communications and a modern airport; and it is able to move through the water for several years without refueling at a maximum speed of over thirty-five miles per hour.

Newport News SB&DD Co. Photograph

The pride of Newport News and the American merchant marine is the 990-foot luxury liner *United States*, the fastest passenger vessel in the world.

Because of the maze of interlocking engineering problems and the magnitude of the construction of these large ships, the Newport News Shipyard has one of the largest engineering staffs in industry. More than 1,700 persons are employed in the design, inspection and research departments, and hundreds of other engineers in the production departments. They represent almost every category in the engineering profession.

The training and education of employees has undoubtedly played an important part in the Company's successful shipbuilding record. A total of forty-five trades and occupations are involved in our operations, and a continuous supply of trained personnel is essential. During the past year we expended over two million dollars for education and training. This includes company-sponsored scholarships and a number of internal educational programs, but the major portion of this amount was expended on our Apprentice School. This school is unique in industry. Qualified high school graduates, upon acceptance into the school, receive four years' training in the trade of their choice. During this period they also attend academic classes, and at the end of their four years they will have acquired the equivalent of a junior college education. The boys who show an aptitude for drafting remain in school for an additional year and join the staff of one of the design departments. Enrollment in the school varies with the over-all requirements in the Yard and at present consists of 475 students.

Academic and vocational facilities are assigned to the school for the exclusive training and education of the students. The school furnishes the nucleus of our skilled production personnel and supervision with a resulting increase in the average education level of our employees—above those found in similar industries. This nucleus of trained employees is invaluable in times of emergencies, when fast increases in enrollment are necessary. For instance, in the Second World War our roll reached a maximum of 31,000. During this emergency period we were able to process over forty thousand employees in training courses. Thirteen thousand of these received certificates from the Company's welding school alone.

The highly-competitive business of shipbuilding has required the Company to keep abreast of or, in most instances, to lead in the development of new ideas for the design and building of ships. For this purpose the Shipyard maintains five laboratories for the development of ideas and general research for the betterment of its products. Ship models are towed in the model basin to determine the most efficient hull design; the engineering laboratory investigates the design of steam turbines and their components; metallurgical and welding research problems and the development of new procedures have been carried on over a period of almost thirty years. The Company also maintains a laboratory for model testing and research in the water power equipment field.

It was, therefore, normal procedure for the Company to begin its investigation of the possibility of using nuclear power in a ship's propulsion equipment and to be prepared to adapt the benefits of such power to shipbuilding operations. In 1953, the Company established a nuclear power design organization, and its activities in this challenging new field have grown at such an accelerated pace that the Newport News Shipyard has become the world's largest builder of nuclear ships.

In preparation for this new concept, many of our designers and engineers were sent to various universities and to the nuclear school at Oak Ridge for specialized studies. The personnel directly involved in the design, testing and inspection of the nuclear systems of the five nuclear ship contracts on hand now totals almost 500 persons.

The Company's first activity in the field of nuclear propulsion was a sub-contract with the Westinghouse Electric Corporation for the design, construction and installation work on the Large Ship Reactor project in Idaho. This prototype of the dual arrangement which will drive nuclear-powered surface vessels was successfully operated at full power in September 1958.

In August 1957, the Company was awarded the contract for the construction of the *Enterprise*, the world's first nuclear-powered aircraft carrier, but the award came only after an intensive preliminary design effort to solve the complex engineering and structural problems of such an undertaking. These problems had to be solved before the Navy could decide whether the building of such a vessel was feasible or desirable. The Company's atomic power division, under prime contracts with the Navy De-

Newport News SB&DD Co. Photograph

The first hulls—two 90-foot tugboats constructed by the Yard in 1890—are still in service.

partment for design studies, developed the preliminary machinery plant design and arrangement for the vessel. A group of some forty of the Company's design engineers and naval architects assisted in the preparation of contract plans for the vessel from August 1956 to June 1957. Following the successful development of the contract plans, the award was made, and the *Enterprise,* launched last month, will be delivered in the fall of 1961.

The Company pioneered in the construction of submarines in 1905, when five of the earliest successfully-operated submersibles were built for Simon Lake; more than fifty years later in February 1957, the Shipyard re-entered the field of submarine construction with the award of the nuclear attack submarine *Shark.* This award, together with four Fleet Ballistic Missile submarine contracts awarded since then, were the culmination and direct result of the foresight of management in their decision to enter this new field of shipbuilding. More than a year in advance of the first contract, Yard personnel from various divisions were sent to observe and learn the details of constructing these complex vessels. Large amounts of money were expended, not only for training but for the new equipment and machinery necessary to enter this field, such as the installation of a shore-based steam plant, a large hydraulic keel bending press and many other items.

The 11,000-ton passenger freight liner *Coamo,* which the Company built in 1925, was not an unusual ship. She was ordinary in size and many of our Naval vessels or passenger liners have been more in the news, yet we like to think she typifies the ideals of quality we have tried to accomplish in almost seventy-five years of shipbuilding at Newport News. In closing, I would like to quote in part from an editorial concerning the *Coamo* in the *New York Herald Tribune* of 1930:

"The *Coamo* has docked here, completing the voyage which was interrupted when she found herself abruptly fighting for her life in the Santo Domingo hurricane. The terse record from the log of the ship's captain (states): 'Wind shifting with tremendous force, breaking windows in pilot house, blowing away skylights on boat deck. . . . Tarpaulin being torn off and hatches broken. The driving rain is entering through doors, windows and broken skylights. Ship unmanageable . . . and pounding heavily in rough seas. She is a wonderful vessel to withstand this, being in ballast.' The barometer had gone off the bottom of the scale, and the wind, at 150 miles an hour, was tearing them to pieces, while they wondered whether any fabric put together by man could withstand the smashing hammer blows of the sea.

"The force of wind and waves met in these great storms is incalculable; so also is the force of human resolution which opposes itself to them. The *Coamo* never failed to rise; her crew did not permit her to falter and she did not betray them. It is a fine story, the more so because for a moment it makes real the verities which underlie even this machine civilization of ours, which is still a partnership of man and their creations against the uncertain savagery of nature. 'Don't praise me,' said the *Coamo's* chief engineer; 'Praise the shipbuilding company. They made a fine ship when they made this one.'

"But the shipbuilding company also is composed of human beings—to be exact, it is the Newport News Shipbuilding and Dry Dock Company—and so even the ship comes down in the end to the skill and ingenuity and honest workmanship of men. Before these even the hurricane is unsuccessful."

giant guardian...

Four football fields could be laid out on the flight deck of the giant, nuclear-powered U.S.S. Enterprise—the world's largest ship. But size isn't the only dimension that makes the Enterprise outstanding. Pressurized water nuclear reactors, producing over 200,000 horsepower, will drive her at speeds in excess of 25 knots. She will be able to sail the seven seas for several years without refueling.

Carlson corrosion and heat-resistant stainless steel plate was used in this huge Attack Aircraft Carrier, and in her nuclear power plant. The builders of the Enterprise have confidence in the stainless plate produced by Carlson specialists. Exacting quality standards and dependable delivery result from such specialization.

Whether you are building a gigantic ship, a nuclear power plant, or corrosion-resistant process equipment, we can help you make it best. For practical assistance in filling your requirements for stainless plate in a wide range of grades and sizes, contact Carlson.

Our new booklet, "Producing Stainless Steels . . . Exclusively," is available. Write for your copy now.

Photograph of the launching of the U.S.S. Enterprise. Courtesy of Newport News Shipbuilding & Dry Dock Co.

OFFICIAL U.S. NAVAL PHOTOGRAPH

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.
Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

COMMANDER BERNARD M. KASSELL, USN (Ret)

MARINE ENGINEERING NOTES FROM THE SOVIET PRESS

THE AUTHOR

enlisted in the Navy in 1931, and served continuously until his retirement. He attended Cornell University and Maryland University, obtaining his B.S. degree in Military Science from the latter institution. He has had a wide range of duty assignments, including tours as Engineer Officer and Repair Officer on various ships and tenders. He was recently stationed in Casablanca, Morocco as Commanding Officer, Military Sea Transport Service and retired after 29 years of active duty. His last duty station was in the Office of the Chief of Naval Operations. Is now engaged in consulting and independent research on Soviet affairs.

RESULTS OF THE 1960 BUILDING PROGRAM

THE SOVIET UNION'S need to augment and expand its merchant marine rests squarely on an announced, and often reiterated, policy of expanding foreign trade. The propaganda value of visits of Soviet ships to foreign shores is exploited to the fullest. One of the tankers in the Soviet fleet, *Kakhovka,* for example, recently delivered a load of oil to Cuba, a not unusual occurrence these days. The unusual feature, from our standpoint, is the fact that, in the course of the stay in port the Soviet crew invited port workers and children on board to indulge in the singing of Russian songs. *Michurinsk* crew members had as their guests students from Havana University. The discussion involved life in the Soviet Union, politics and related subjects. *Dmitriy Pozharskiy* played host to port workers in Calcutta, showing them Soviet motion picture films. Many of the ships field soccer teams compete against local teams, the two then returning to the Soviet ship to "get better acquainted." Finally, there is the study program whereby foreign students are brought to Moscow to study, as was the case in the recent report of 100 Cuban students having embarked in *Kooperatsiya,* the first such group to visit the Soviet Union.

In between times the ships carry cargo, of course, and in ever-increasing quantities. The two programs, trade and propaganda, which could, in fact, be classed as a single program, require ever-increas-

ing numbers of merchant ships of different types. The program of expansion for the period ending in 1965 called for double the tonnage available in 1958. Progress was reported recently in a statement issued by N. G. Byikov, Chief of the Administration for the Ordering and Supervision of Construction of the Fleet, Ministry for the Maritime Fleet.

According to M. Byikov 1960 can be termed a year of intensive augmentation of tonnage. Deliveries increased 150 per cent over the 1959 figures, resulting in an increase in the average cargo deadweight of more than twice the old figure among the tankers and more than 20 per cent among the dry-cargo types. In the course of 1960 the Soviet flag was raised over 10 different types of ships, including icebreakers, each of which was the first of a series.

Soviet shipyards produced the first gas turbine propelled ship ever built within the country in *Pavlin Vinogradov* (see the JOURNAL, November 1959, p. 709) designed to carry timber in the foreign trade. An additional innovation is the installation of mechanically operated hatch covers, in use in other classes of ships as well. Another Soviet first is the installation of a controllable pitch propeller and roll dampers in the cotton-timber carrier *Geokchay*, an *Inzhener Belov*-class (see the JOURNAL, November 1960, p. 685).

Since Soviet marine engineers had no experience with similar ships, some difficulty was encountered in operations. In addition, designs were not always correct, resulting in certain changes to succeeding ships in the various classes. Just how extensive the difficulties may be, or how long it will take to iron them out and make the individual ships fully operational, is hard to say. Past experience indicates, however, that the operators should shake down in a relatively short time. In fact, they will have to in order to provide trained personnel to go to the new construction underway. It is claimed that Soviet shipyards will, in the period 1959-1965, produce 2.3 times the number of seagoing transport ships delivered in the previous seven year period.

Then there is the contribution from foreign yards. Among the new types are *Aragvi* and *Kura*, banana boats built in West Germany and part of the 1960 delivery. A third of this class is expected this year. Poland delivered four of the 5,000 ton cargo carriers classed as timber carriers in the *Volgoles* series and is expected to deliver seven more this year. East Germany's 1960 delivery schedule included six coal-ore carriers with 5400 horsepower main propulsion plants, capable of lifting 9750 tons and operating at 15 knots. This too is a continuing program, one which will add a considerable capability since the hatches are wide and cranes have been installed instead of booms. Denmark delivered two large, dry-cargo carriers, *Tiksi* and *Ussuriysk* (the latter referred to in other reports as a refrigerator type), of 10,000 tons capacity for general cargo and 13,000 tons for bulk cargo. The 10,000 horsepower main propulsion plants provide these ships with an 18 knot speed capability. Hungary delivered *Tartu*, 1200 tons capacity, 1000 horsepower and 11.5 knots, as part of a program which has already seen six of this type delivered and which will continue on this year and beyond. The fact that the class has the engine controls in the wheel house has contributed to reducing the number of men needed to man the ship, always an attractive feature in the manpower short Soviet Union.

It is noted that all of these ships have been equipped with the very latest equipment available in an effort to make the ships comfortable for the crews and easy to handle during cargo operations. Such design change as wider hatches have been called with the result that cargo formerly deck-stowed now goes below decks. Other trends are towards larger ships with increased main propulsion plant horsepower. Diesel engines are increasing in popularity for these larger propulsion units.

M. Byikov claims that ships now under construction for delivery in 1961-1962 will have 19,000 horsepower diesel propulsion units. Operations of *Ugleuralsk*, built in East Germany, and first of a series to operate in the Black Sea, indicate that motorships of the type are quite profitable, a fact which has aided the planner in settling on the motorship as the basic merchant marine class.

Soviet orders are on the books and cover deliveries for 1961, and coming years, from shipyards in Finland, Denmark, East Germany, Poland, Bulgaria, Hungary, Yugoslavia and Japan. Yugoslavia, according to the official news agency Tanjug, has signed a 5-year agreement which includes the delivery from Yugoslav shipyards of 16 25,000 ton cargo deadweight tankers and 9 cargo carriers of 10,000 tons capacity. The first of the tankers, *Trud*, was placed in service early in the year and by late March was on her way to Rotterdam with 23,000 tons of diesel oil loaded in Tuapse. *Trud* has a steam turbine installation and is capable of some 15 knots, according to reports. Japan is involved in deliveries to the tune of almost $36 million, the price tag for four 35,000 ton deadweight tankers and three cargo carriers of 12,000 tons deadweight each.

The end result of the expansion program will be a stepped up flood of Communist propaganda. This will be further increased when the new passenger liner program becomes reality. This program involves the construction of one-class passenger liners (see the JOURNAL, February 1961, p. 74) in the Leningrad area. Ships of this type are scheduled for operations in the Black Sea, in the Far East, and on tourist voyages around Europe, as well as to countries in the near and middle east.

Listed below are the merchant ships, auxiliaries, and special craft noted as having been delivered, or which were indicated as under construction, and first noted in the past three months:

Name	Where Built	Type	GRT
Alapayevsk, m/v	Finland	Cargo	5513
Aleksandr Matrosov, m/v		Cargo[1]	2287
Amguema, d/e		Cargo	7968
Arsenyev, d/e			
Atlantik, m/v	USSR	Trawler	
Atlas, d/e	USSR	Salvage-Rescue	828
Debaltsevo, s/s	East Germany	Cargo	5628
Dobrinya Nikitich	USSR	Port Icebreaker	
Dozornyiy, m/v		Tug	
Dvinoles, m/v	Poland	Timber Carrier	4200
Elektrokhod		Refrigerator	
Gauya, m/v		Cargo	
Gyurgyanneft, m/v	Bulgaria	Tanker	3000
Ingur, m/v	West Germany	Refrigerator[2]	4410
Kuprin, m/v	Poland	Factory-Trawler	2670
Lenkoran, d/e	USSR	Car Ferry[3]	
Matelot, s/s	Poland	Trawler	647
Metallurg Kurako, s/s	USSR	Cargo	12016
Metrostroy, s/s	Poland	Trawler	647
Mga, m/v	Hungary	Cargo	1194
Molodogvardeyets, s/s	Poland	Trawler	647
Murgab, m/v	USSR	Cotton-Timber	3000
Murmantsanin, s/s	Poland	Trawler	647
Neftechala, m/v	Bulgaria	Tanker	3000
Pamyat 26 Komissarov, m/v	Bulgaria	Tanker	3000
Polyarnyiy		Refrigerator	
Rava Russkaya		Tanker	
Razdolnoye, m/v	East Germany	Cargo	3359
Repino, m/v	East Germany	Cargo	3359
Severoles, m/v	Poland	Timber Carrier	4200
Shamkhor, m/v	USSR	Cotton-Timber	3000
Shantar, s/s	Poland	Cargo	4180
Simferopol, d/e	USSR	Refrigerator	5217
Sinegorsk, m/v		Cargo	
Sofiya, d/e	USSR	Tanker[4]	
Sovetskaya Rodina, d/e		Refrigerator	
Sovetskiy Sakhalin, s/s	Poland	Fishing Base	11540
Svetlogorets		Cargo	
Trud, s/s	Yugoslavia	Tanker[5]	
Ushinskiy, m/v	East Germany	Cargo	5628
Velsk, s/s	Poland	Cargo	4180
Vernyiy, d/e	USSR	Whale Catcher	844
Vozhnyakova, s/s	Poland	Cargo	4180
Zhelez, s/s	Poland	Cargo	3812
Zhokhannes Vares, s/s	Poland	Fishing Base	10036

1. Recently completed major overhaul which included superstructure and cargo-handling gear changes.
2. Although classed as refrigerators, this class, now numbering three, has engaged in the banana-pineapple trade between the USSR and Guinea.
3. First of the class. For use on the Caspian Sea between Krasnovodsk and Baku.
4. Reportedly will, when completed, displace 60,000 tons.
5. First of 16 to be delivered; 25,000 deadweight tons.

DRYDOCK FOR FAR EAST

The Baltic Shipyard in Klaypeda built a floating drydock equipped with its own power plant, shops, and modern equipment for use in repairing ships of the fishing fleet in the Far East. Two tugs and a cargo ship were assigned to tow the dock to its destination and it had reached Port Said by late in March.

REINFORCED-CONCRETE BASE SHIP

A reinforced-concrete base ship, to be used by the fishermen in the Caspian Sea region, is under construction in the Gorodets Shipyard, the first of such bases on order. The ship will displace 3500 tons on a length of 280 feet and a beam of 59 feet. The first of the six, as yet unnamed, is scheduled for launching this summer.

ELECTRIC-DRIVE MOTOR BUILT

The Kharkov Electrical-Mechanical Works is building an alternating current, electric drive motor rated at 2600 kilowatts, the first such motor ever built in the Soviet Union for use in one of the seagoing refrigerator ships now under construction.

THE TRAWLER *Leskov*

Most recent of the trawler classes coming into service under the Soviet flag is the *Leskov* class,

built and building in Gdansk, Poland. At last accounts eight were on order, of which three, possibly four, have been delivered.

This is a single-screw ship with the main engine amidships and a ramp in the stern. Built to the Register of the USSR class LR 4/1S (Trawler), the ship can stay at sea for some 70 days, during which time the catch can be processed, frozen in the holds provided, and the waste products converted into meal and oil.

For comparative purposes the characteristics of the new class are listed along with those of the *Mayakovskiy* class and the *Pushkin* class, the former built in the USSR, the latter in Germany:

	Leskov	*Mayakovskiy*	*Pushkin*
Length overall, feet	280	278	277
Length between perpendiculars, feet	246	246	246
Beam, feet	45.2	46	44
Height of side to main deck, feet	23.3	24	24.1
Height of side to shelter deck, feet	32	32.8	32.8
Draft (designed), feet	17.7	18	17.1
Coefficient of displacement	0.62	0.576	0.665
Coefficient of fineness of waterline	0.85	0.785	0.82
Coefficient of fineness of midship section	0.94	0.974	0.957
Longitudinal coefficient	0.66	0.59	0.695
Displacement, empty, tons	2298	—	2235
Deadweight, tons	1240	1301	1242
Gross registered tons	2670	3170	2472
Volume fish refrigerated holds (net), cubic feet	47300	41700	47600
Speed, knots	12.5	12.5	12.5

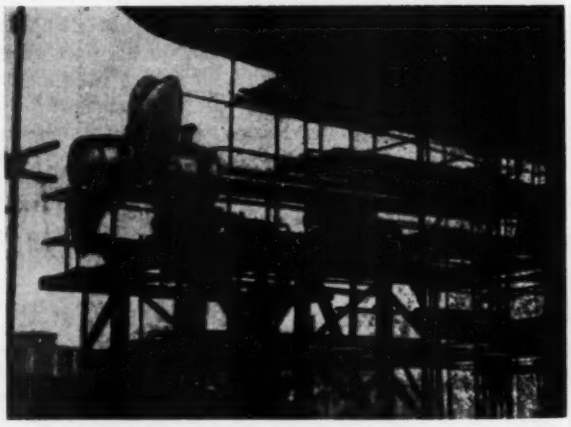
Leskov uses an 8-cylinder Sulzer diesel engine for main propulsion, the 8TD48, which has the following characteristics:

Power, hp	
rated	2000
maximum	2400
Number revolutions per minute	
rated	187
maximum	225
Fuel consumption, ounces/ehp/hour	5.3
Size, feet	27.8×7.5×17.7

Power and lighting are provided from four diesel-generators rated at 250 kw each, direct current, and an emergency diesel-generator of 22 kw. The diesels are 6-cylinder models 6VAN22 and two of the four units can be operated to provide power to the trawl winch. An auxiliary boiler and an evaporator plant are also installed, the latter able to distill 5 tons of water a day.

Leskov has been equipped with a controllable pitch propeller (see cut) manufactured by the Lips-Schelde Co. of Holland. The propeller is of bronze, four-bladed, with a diameter of 122 inches and is of the tandem type, consisting of two propellers on the same shaft, rotating right-handedly.

Surprisingly enough, the admitted shortcoming of the class, and the same is true of all similar classes,



Lips-Schelde CPP installation for trawler *Leskov*.

is that it is designed to handle only cod and perch. Another fault is that, because of the sail area provided by the high sides, all classes tend to drift badly when trawling with the result that trawling speed cannot be properly maintained without causing excessive wear on the wires and blocks involved, and, in addition, causing excessive operation of the steering gear in efforts to maintain course. However, most of the deficiencies encountered in the other two classes were bred out of the *Leskov*, so to speak, with the result that it is now designated as the future trawler class for active maritime fishing activities.

FLOATING SHOPS

The floating shop, or tender, may, or may not, be used to provide services to merchant and fishing types but, as will be seen from the following account, there is nothing to prevent its being used to service naval vessels, despite the fact that building was in accordance with the Rules for the Classification and Construction of Steel Merchant Ships, established by the Maritime Register of the USSR.

The ship is designed to provide repair services of a voyage and emergency type to ships as well as to manufacture spare parts in areas where no bases ashore exist.

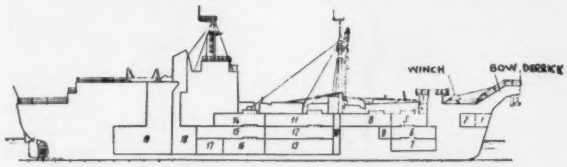
Apparently in the design stage, the self-propelled type is to follow the *Freza*-class (also listed as the PM series, eight of which have been identified and most, if not all, of which have been towed to the Far East) of 562 GRT, a non self-propelled series. The new tender is said to have the following characteristics:

Length overall, feet	370
Length between perpendiculars, feet	328
Beam, greatest, feet	54
Height of side to main deck, feet	32
Mean draft (at full displacement), feet	15
Full displacement, tons	4500
Main propulsion, horsepower	2000
Speed (calculated), knots	11
Cruising radius, miles	3000

Endurance, days	30
Crew members	47
Production workers and helpers	376

Space is also to be provided for 34 temporary workers and helpers, in addition to the above. A bow derrick is to be installed which will be able to lift 150 tons. Ten shops (see cut) are provided as a production division, some of which contain, or carry out, more than one type of operation.

Main propulsion is to be provided by one 8DR 43/61-V1 diesel engine. However, some question has arisen as to the advisability of using electric drive, and this latter may come into use.



Sketch plan of compartment arrangement in floating ship or tender, now in the design stage. 1—Foundry sand stowage; 2—Sail locker; 3—Welding shop; 4—Paint locker; 5—Carpenter and rigging shop; 6—Main issue room; 7—Main storeroom; 8—Electrical shop; 9—Radio repair shop; 10—Elevator; 11—Shipfitter shop; 12—Light and medium machine shop; 13—Heavy machine shop; 14—Hull-boiler shop; 15—Hot and cold bending section; plating; 16—Foundry; 17—Blacksmith shop; heat treatment section; 18—Boiler shop; 19—Engine room.

ARCTIC CARGO CARRIER

The diesel-electric cargo ship *Amguema* is the first of a new series of icebreaker-transport ships building for use in Arctic waters. The design of the new class incorporates lessons learned in the course of operating the *Lena* class, a series built in the Netherlands commencing about 1954. One of the ships in the class, *Ob,* has become famous as a result of the many trips made into the Antarctic, so that it would be supposed that naval architects working on the new design had ample experience to draw on for the new ship. The following comparison is available between the new ship and *Angara,* completed in 1957 and herself a veteran of both Arctic and Antarctic operations:

	Angara	*Amguema*
Length overall, feet	428	438
Beam, feet	62	62
Height of side, feet	36.7	38
Own weight, tons	5110	4840
Normal draft, feet		
with general cargo	25	25
with bulk cargo	27	29
Designed draft, to cargo marks, feet	27	30
Cargo carrying capacity, tons		
general cargo	4810	5000
bulk cargo	6100	7400
Deadweight, tons		
general cargo	6265	6300
bulk cargo	7430	8700
Deeptank capacity for cargo fuel, tons	1200	None
Gross registered tons	7550	7968
Net registered tons	4300	3435
Power of main diesel engines, ehp	4×2050	4×1800
Speed at draft of 25 feet, knots	15.4 (actual)	15.0 (guaranteed)

The Icebreaker-Transport Ship.

We are reminded that the construction of icebreaker-transport ships was begun in order to provide transportation for the rapidly developing areas of the northern part of the Soviet Union. Ordinary ships, it was found, were unable, even when ice-strengthened, to meet the demands placed on them since icebreaker protection and help were needed to get them through the heavy icefields. Under conditions such as these speed was reduced to a few knots and delays were encountered. Considerations entering into the design include the form of the ship's lines, the strength of the ice protective belt, the horsepower of the main propulsion plant, the type of ballast system to be installed in order to provide adequate protection to the propeller when the ship is in ballast, the retention of good sea-keeping qualities when operating in clear waters, and the assurance of making maximum use of the cargo cube. All these considerations brought the architects to icebreaker hull lines. The propulsion finally settled on was diesel-electric because only this system provided a constant source of power to a propeller operating under changing conditions of torque.

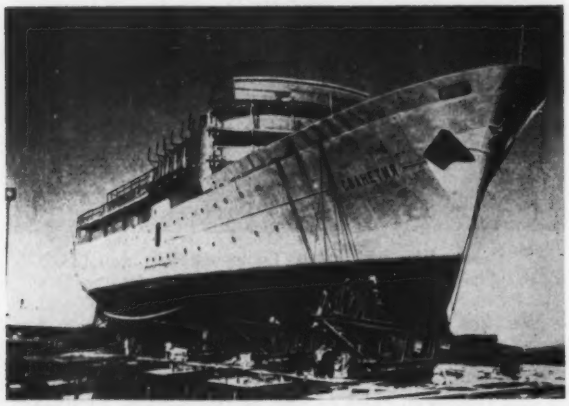
These considerations were introduced into the planning for the *Lena* series. However, the icebreaker features were not sufficiently strong in certain sections of the hull and the volume of the tween-deck over the deeptanks made cargo operations difficult.

Faults such as these were eliminated in the design of *Amguema,* which is a single-screw, two-decked, full-scantling ship classed in the Register of the USSR as UL R4/1 (Arctic).

There is, at this time, no indication as to the scope of the program, nor has the building yard been indicated.

OCEAN-GOING PASSENGER LINER

The scheduled passenger liner mentioned in the "Notes" of February 1961 (p. 74) is to be built in the Leningrad area, according to reports emanating in Moscow in mid-March. Displacement is given as 28,000 tons for the 1,000 passenger liner, biggest of the type to be undertaken in the Soviet Union to date.



***Svanetiya*, third of a series of passenger ships under construction in the Soviet Union for the Caspian Sea, on the ways.**

FINNISH-BUILT ICEBREAKER *Moskva*

According to the terms of the trade agreement between Finland and the Soviet Union, Finland is to provide, for the Soviet Union, two large icebreakers, *Moskva,* delivered in 1960, and *Leningrad.* Recently complete details of the former ship were released and, according to the data, the two ships have the following characteristics:

Length overall, feet	400
Length at the load water line, feet	370
Beam, greatest, amidships, feet	81
Height of side to upper deck, feet	46
Height of side to main deck, feet	37.7
Draft carrying minimum stores, feet	26
Draft, greatest, feet	34.5
Displacement, load-line, in sea water, tons	13290
Deadweight, tons	4221
Coefficient of displacement, load-line	0.511
Sustained power at the main engine flanges, hp	26000
Sustained power at the propeller shafts, hp	22000
Maximum speed (at load water-line draft), knots	18.3*
Maximum thrust, tons	226*
Number of men in crew	101

* According to data obtained from model tests.

Construction of *Moskva* was in accordance with the rules of Lloyd's Register, to Class 100A1, with considerations being given to the rules of the Register of the USSR in such matters as living and working spaces, life boats, emergency installations and fire fighting equipment, cargo handling gear, normal and emergency lighting. The Wartsila Co. has built a ship fitted with three propellers, diesel-electric propelled.

At maximum draft the ice-protective belt is extended 3.28 feet above the water line and continues down to 8.4 feet below minimum draft. In the bow the protection runs to the keel. The icebreaker has been fitted with two electrically operated, 1.5-ton cranes, located on the forecastle, rotatable through 360 degrees, and two 10-ton cranes in the stern.

The Icebreaker *Moskva*.

An automatically operated towing winch is installed in a compartment aft and steering is accomplished through an electro-hydraulic system with controls in the wheel house, on the flying bridge and at an after steering station.

Main propulsion diesel engines, eight in all, operate the main generators which, in turn feed three main drive motors. The diesels are 9-cylinder, nonreversible, two-cycle Wartsila-Sulzer type 9MH51 with the following characteristics:

Bore, inches	19.89
Stroke, inches	21.45
Power per cylinder, horsepower	
at 300 rpm	3250
sustained	2750
Fuel consumption at full power, ounces/ehp/hour	5.775

The engines can maintain a ten per cent overload for one hour and, for a short time, will handle a twenty per cent overload.

The main generators are type GM434/80-80, direct current, with a sustained rating of 2150 kw,

600 volts and an ampere rating of 3600. The main drive motors for the outboard shafts are single armature units rated at 5,500 hp, while the amidships motor is a twin-armature unit rated at 11,000 horsepower. All motors operate at a voltage of 1200 and rated current of 3600 amperes. Rated speed of rotation is 115-145 rpm with an increase in speed up to 190 rpm permissible.

The propellers have replaceable blades and are made of open-hearth steel containing a 3 per cent nickel additive.

Ship's service lighting and power is provided for by six synchronous diesel-generators, three-phase, alternating current, rated at 350 kw each at 400 volts. All generators can be paralleled. At-anchor and emergency diesel-generators are also installed. The power net is 380 volts, the portable units have 220 volt outlets while lighting is fed from a 127 volt net. An additional, low voltage net, 12 volts, is also provided.

Leningrad, launched in Helsinki in October 1959, should be coming into service this year.

FERRY-BOAT CONSTRUCTION

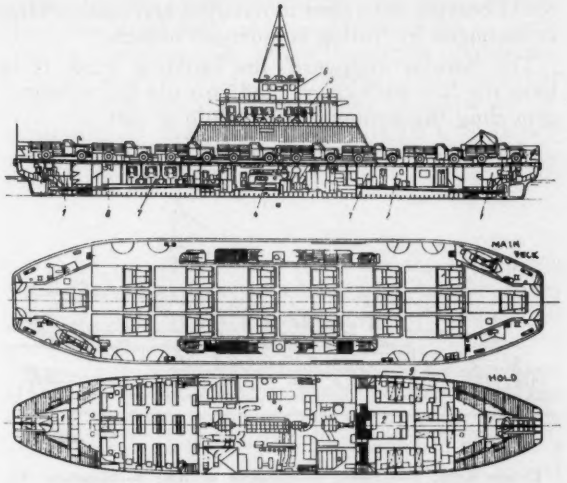
Reports of ferry construction date back some years (See "Notes" in the JOURNAL, May 1958, p. 214). The most recent ferry type is one designed to meet the specifications of the River Register of the USSR, Class "O" for use on the lakes and reservoirs of the Soviet Union. This class, as distinguished from a smaller type which went into operation in 1959, is somewhat larger:

	1960	1959
Length overall, feet	195	106
Length, calculated, feet	188	102
Beam, greatest, feet	44	39
Height of side, feet	11.8	10.8
Draft, loaded, feet	6.6	5.7
Displacement, full, tons	830	278
Cargo capacity, tons	185	70
Speed, full, knots	10	8
Main propulsion, horsepower	1000	2×140
Type propulsion	Diesel-electric	Diesel
Crew	18	8

Whereas the 1959 version was designed to carry 8 to 10 trucks and 85 passengers, the more recent version will handle 20 trucks and 212 passengers. Both are double-enders, designed for shuttle operations over short runs and in certain ice conditions.

LLOYD'S REGISTER

Despite the fact that ships built for the Soviet Union usually are constructed in accordance with the rules of the Register of the USSR, certain of the deliveries have been built in accordance with Lloyd's Register rules. In addition to *Moskva* and *Leningrad,* the icebreakers built and building in Finland, several other ships built in Finland have come under the Lloyd's system. In 1959 Japan built four ships, Sweden built two to these same rules and the *Pioneer* class of trawlers, built in England, also complied with the requirements of the organization.



General arrangements in ferry-boat for use on lakes and reservoirs. 1—Tiller room; 2—Crew's mess; 3—Galley; 4—Engine room; 5—Passenger space, 122 persons; 6—Wheelhouse; 7—Passenger space, 82 persons; 8—Ventilators; 9—Crew's cabins.

SELF-PROPELLED CRANE SHIP

Among the increasing number of ships assigned to the technical categories of the river fleet in the Soviet Union is the recently announced self-propelled crane ship to be used on the large rivers and reservoirs throughout the nation. Its operations are to include the finding and removal of obstacles in fairways, raising small, sunken ships, setting and removing the heavy buoys used as aids to navigation, handling mooring clusters and anchors, and doing other types of routine maintenance work. By so doing the crane ship will eliminate the need to build special ships for use by divers, certain types of dredgers, buoy tenders, etc.

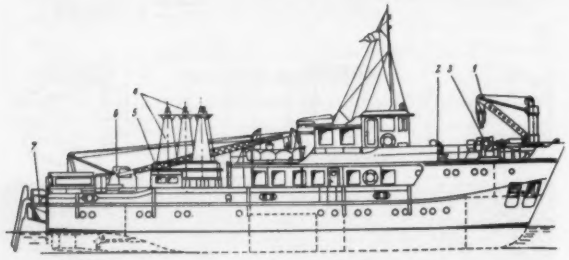
The crane ship series is to be self-propelled and will have the following characteristics:

Length, overall, feet	102
Length, calculated, feet	92
Beam, greatest, feet	32
Beam, calculated (for draft of 5.25 feet), feet	29.6
Height of side, calculated, feet	9.5
Draft, empty, with one day's fuel supply, feet	4.3
Displacement at draft of 4.3 feet, tons	244
Main propulsion installation, kw	200
Speed, calculated, knots	7
Crew members (including three divers)	13
Endurance, days	10

Two main diesel-generators, mark DG-100/1, rated at 100 kilowatts each at 400 volts, provide main propulsion. The main drive motor is a mark AK 112-10 unit, rated at 125 kilowatts at 380 volts driving an impeller 3.1 feet in diameter at 585 rpm, maximum, in the water-jet piping arrangement fitted under the stern. The propeller-rudder combination in this instance was selected to provide the crane with a high degree of maneuverability and to eliminate projecting parts under the hull which

could become entangled in mooring and anchor lines or damaged by hitting submerged objects.

The Saratov Shipyard, the building yard, is to have the first such crane ready for use this summer, providing the announced schedule is met.



Crane Ship. 1—Crane; 2—Electric winch; 3—Capstan; 4—Lake-type buoys; 5—Diving locker; 6—Fully rotatable, automobile type crane; 7—Diving area.

DRY CARGO CARRIER *Leninskiy Komsomol*

Late in 1959 *Leninskiy Komsomol*, first of a series of turbine-drive cargo ships, completed her underway trials, as did a sister *Fizik Vavilov*. Details were withheld for a year in order to obtain an evaluation of their characteristics in actual operations, since the selection of the capacity and speed had been determined by the need to use the ships for carrying general and urgently needed cargoes over long distances in foreign trade.

Built to class LR4/1S of the Register of the USSR, announced characteristics are:

Length overall, feet	556
Length between perpendiculars, feet	510
Beam, feet	72
Height of side amidships, feet	42
Draft to cargo mark, feet	32
Draft with specified cargo of 10,000 tons, feet	27.5
Deadweight with specified cargo, tons	12640
Deadweight with full load of cargo, tons	16000
Displacement with specified cargo, tons	18840
Displacement with full load, tons	22200
Rated horsepower of main propulsion plant	13000
Cruising radius under normal operations, miles	12000
Speed with full cargo, knots	18.5
Hold space for general cargo, cubic feet	716874
Number crew members	42

Use of the low-alloy steel SKhL-4 enabled the builders to construct a ship which weighs 2.34 pounds per cubic foot LBH, which compares with the figure of 5.6 pounds per cubic foot for the *Mariner*-class hull.

The geared turbine unit for main propulsion was selected in order to make use of the lower fuel costs involved in burning cheap, poor grade, sulphurous mazuts, M-60, M-80 and M-100 in the boilers. Results of this decision, in so far as boiler conditions are concerned, are not available. The boilers, two type KVG-25 units, have automatic combustion control installations for controlling the production of 25 tons of steam per hour at 630 psi, superheated to 878°F, fed to the TS-1 turbine.

This class, largest cargo carrier class to be built to date, compares with previously built classes as follows:

	Leninskiy Komsomol	*Lenino-gorsk*	*Arkhangelsk*	*Liberty*
Volume of holds, net, ft³	716874	590000	485000	475000
Number of holds and hatches	6	5	5	5
Number of decks and platforms	2	3	3	2
Height of tween-decks, feet (theoretical)	10.8	10.8	9.5	9.2
Area of cargo hatches, ft²	6000	3760	3800	3000

Holds 3 and 4 are serviced by 60-ton heavy lift booms which can also be rigged to service holds 2 and 5 as well.

Sent to the Far East after acceptance, *Leninskiy Komsomol* en route from Odessa to Vladivostok via Singapore, made 18 knots at 95 engine rpm, and 19 knots at 99-100 rpm. One ballast run from Vladivostok to Shanghai was made at an average speed of some 22 knots. After taking 13,000 tons of rice in Shanghai the ship returned to Odessa where it was established that the ship had covered 9000 miles at an overall cost per ton-mile of operation of 0.85-0.90 kopeck, or, on a per ton carried basis, 76-81 rubles. The figures include port time and time in ballast.

Maximum profits from use of ships of this class, because of their size, must be derived by their use over long runs, on tight schedules, with full cargos available at both ends of the run but bunkers taken on board only in Soviet ports. Care must be given to water depths in the ports of destination, however, for lighterage charges and the time lost in such operations could make such runs unprofitable.

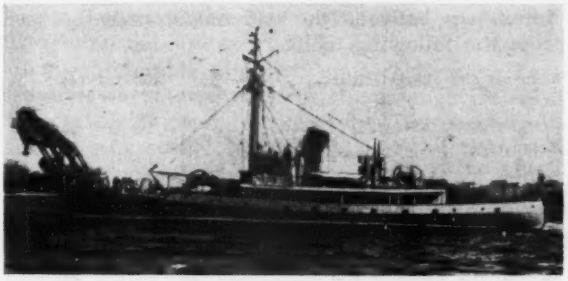
MOORING TENDER

An unnamed mooring tender, capable of lifting 75 tons with its bow derrick, was turned over to the Soviet Union by the "Neptun" Shipyard in East Germany some time ago. For use in Black Sea ports, the tender was built to the rules of the Register of the USSR, class ULR-4/1S under the supervision of the East German ship classification society DSRK.

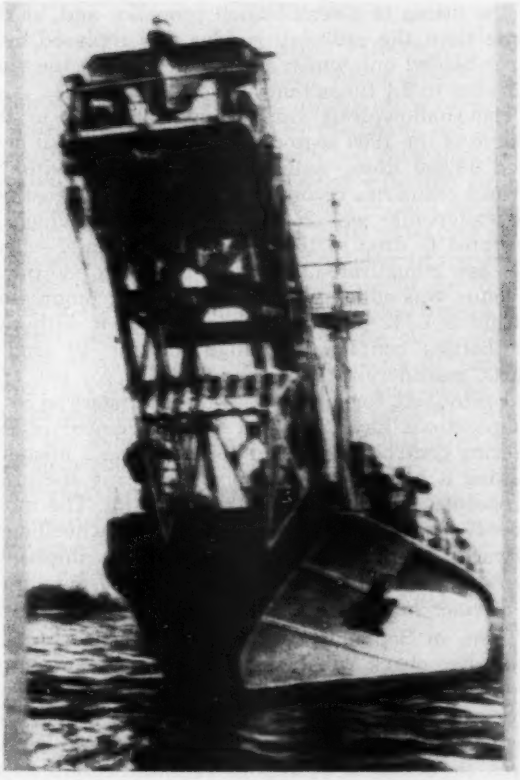
The announced characteristics include:

Length, including bow derrick, feet	189
Length overall, feet	170
Beam overall, feet (including rubbing strakes)	37.6
Height of side to main deck, feet	16.4
Full displacement (100 per cent stores and load weighing 75 tons on the bow derrick), tons	1241.5
Mean draft, feet	12.4
Deadweight, tons	315.8

Capable of operating in any waters, the fuel supply, boiler feed water capacity and storeroom cube



Mooring Tender



Bow View of Derrick Arrangement for Mooring Tender.

is such that the ship can remain at sea for 10 days, in which time it can cover over 2500 miles at a speed of about 11 knots, retaining, at the same time, a 20 per cent reserve fuel and water supply.

The accompanying photographs indicate the bow configuration, as well as the details of the stern and topside. Quarters are provided for a 41 man crew and a hold, located between frames 15 and 28, from forward to aft, can take 5200 cubic feet of general cargo.

Main propulsion is provided by two vertical steam engines, triple expansion types, rated at 500-ihp at 135 rpm. Two three-burner fire-tube boilers generate steam at a rate of 3.84 tons per hours.

The derrick frame extends a little over 26 feet above the main deck and the derrick itself is operated by a steam winch. When the ship is used to lay mooring clumps or anchors, special rigs are available for automatically releasing the clump or anchor when it is in place. Winch drive is by a 95 horsepower steam engine consisting of two, single cylinder machines.

WHALER BASE LAUNCHED

Almost one year to the day after the sailing for the Antarctic of the first of the huge whaler bases built in the Soviet Union, *Sovetskaya Ukraina,* the second of the series, *Sovetskaya Rossiya,* slid into the water in Nikolayev. The way time for the latest of the series is reported to have been one-third less than for the first ship.

As a result of the experience gained in operating *Sovetskaya Ukraina* the designers were able to add additional equipment so as to process four kinds of whale products instead of the one or two originally planned. In addition, some improvement has been made in working and living spaces so as to make things more comfortable for the whaler's crew.

It is expected that the new whaler base will join in the forthcoming season's work in the Antarctic.

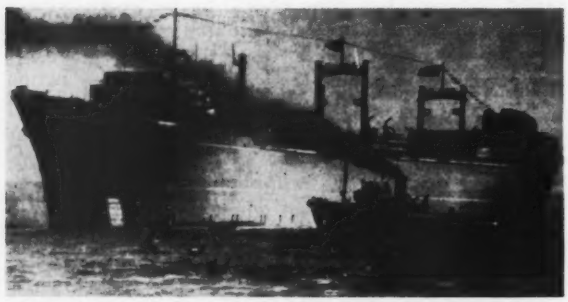
HYDROFOIL EXPERIENCE AND DEVELOPMENT

An All-Union Scientific-Technical Conference on Hydrofoils was held in Gorkiy in November, 1960, under the auspices of the Gorkiy Oblast Administration of the Scientific-Technical Society of the Shipbuilding Industry. The purpose of the conference was to take an all-around look at the problems connected with the building of ships of this type.

Results of operations of *Raketa* and *Meteor* were discussed. *Raketa,* eleven of which class have been noted thus far, has been operating between Gorkiy and Kazan, a distance of some 250 miles, since going into service in 1957. Since that time the craft has covered 99,300 miles and has carried over 44,000 passengers, 20,000 in 1960 alone. Average speed with the current has been about 30 knots; somewhat less in the upstream direction. *Raketa* has, the reports say, proven to be reliable in operation and has good afloat qualities. Even when the craft has gone aground the damage has not been serious. At the end of the 1959 season, in returning to her base from Kazan, *Raketa* ran through ice 2 inches thick with no hull damage and only slight scouring of the wing struts on the foils. A second craft, *Raketa-6,* was put on the Kuybyishev-Saratov run in 1960. This run is over a distance of 263 miles and, in the course of the season *Raketa-6* logged 31,260 miles, carrying 29,420 passengers. The season's time was split up as follows:

Underway	23.9 per cent
Maneuvering	2.5 per cent
Standing time	52.2 per cent
Time in repair	21.4 per cent

Sovetskaya Rossiya **starting down the ways. Note stern ramp opening through which whales are drawn on board. Home port name on stern is Vladivostock, in the Far East.**



Latest Soviet Whaler Base, ***Sovetskaya Rossiya,*** **immediately after launching.**

Passenger capacity was used at 75 per cent of total and the overall cost of carrying one passenger was fixed at 16.5 copecks per passenger-mile.

In 1960 yet another *Raketa*, specially equipped to operate in shallow water, started operations on the upper Dnepr River between Gomel and Kiev. The differences between the two models may be seen from the following table:

Elements and characteristics	*Raketa* types	
	Regular	Shallow-draft
Length overall, feet	88.5	88.5
Beam, feet	14.4	14.4
Draft, feet		
on the hull	5.9	3.8
on the foils	3.6	1.64
Displacement, full, tons	25.35	22.8
Engine horsepower	750	800
Operational speed, knots	26	24
Number of passengers	66	48

The reduced draft was obtained mostly as a result of the fitting of a semi-loaded propeller and, at the same time, the ordinary rudder was replaced by a three-bladed one which served to increase the rudder area to 2.1 times that of the ordinary one.

The shallow-draft version made 96 trips in the course of the 1960 season, during which time it covered 19,800 miles with 6628 passengers, with no serious casualties recorded. On this run the cost per passenger-mile was 26 copecks, a figure which is expected to drop to 16.7 when regular, daily schedules are inaugurated. One way in which additional revenue was added was to remove the compressor, weighing 1,342 pounds, and to replace it with two air bottles containing enough air for 40 engine starts, considerably more than needed for one trip and providing for an increase in passengers to 56.

Operations have revealed that placement of the steering controls and wheel house aft was a mistake, making it hard to see ahead and causing the craft to operate at reduced speeds as a result. The more recent versions, therefore, carry the wheelhouse forward. Automation of various of the shipboard operations will, it is claimed, reduce the 7-man crew to a lesser number eventually.

Then, in September, 1960, the 150-place *Meteor* made her check run from Gorkiy to Ulyanovsk, a distance of 380 miles in 9 hours and 3 minutes of underway time. Forty six minutes were spent in maneuvering, approaches to landings and departures, the schedule calling for 12 intermediate stops. Average underway speed was stated to have been 36 knots and, because of the excellent visibility in this model, at no time did the craft have to slow down because the captain was uncertain as to what was ahead. After several such runs the *Meteor* was transferred to operate Gorkiy-Kazan-Gorkiy. In what was left of the season *Meteor* covered 6,300 miles and carried 3,200 passengers.

Today the latest, the biggest version of the Soviet family of hydrofoils, *Sputnik*, 300 passengers, is nearing completion. It will operate on the large reservoirs, as well as on the rivers. In addition, the construction of a seagoing hydrofoil, also carrying 300 passengers, has been started. This latter is said to be designed for operation in seas with 15-20 foot waves running and at speeds up to 30 knots.

In the planning stage is a 30-place hydrofoil for

use in shallow watered areas. This version will draw 1.7 feet on the hull and 1.3 feet on the foils. Beyond this, considerable attention appears to have been given to the design of a cargo carrying version of the *Meteor* as a combination type. The design calls for a craft capable of carrying 15 tons of cargo and 23 passengers. An open deck will carry either vehicles or containers and an anticipated speed, at full load displacement, of better than 37 knots is programmed. The Central Scientific-Research Institute for Water Transportation Economics claims that cargo carriers capable of lifting 10, 27 and 55 tons of cargo can be made from the original designs of *Raketa, Meteor,* and *Sputnik,* respectively.

SHALLOW-DRAFT RIVER TANKER

The Lena River is the main water artery in the Yakutsk Republic, carrying, among other cargo, the petroleum products needed by the farms and industries in the region. Indications are that the area's economy is expanding and, along with the expansion has come the need to move more petroleum products, most of which travel 1,200 miles and more downstream to reach their destinations. In the upper reaches of the river, for a distance of up to 500 miles, the average water depth ranges from 4.6 to 5.3 feet, making it necessary to use shallow-draft barges carrying for 750 to 1000 tons of product towed by tugs. The large crews needed by the barges and tugs, as well as the time taken to accomplish the deliveries, has resulted in increased costs of transportation.

All this has brought about the designing of a shallow-draft tanker capable of carrying Grade I and Grade II (light) products. The first of the type, which has the characteristics shown, is reported to be under construction, according to the project director, A. Birin:

Length of hull, calculated, feet	280
Length overall, feet	283
Beam of hull, feet	41
Height of side, feet	8.2
Main engines, horsepower	2×400
Speed in deep, still water (at draft of 5.2 feet), knots	10

The cargo capacity and draft will depend on the type of product carried and will be somewhat as follows:

Type of product	Cargo capacity, tons	Draft, feet
Diesel fuel, kerosene	1300	6.5
Motor gasoline	1200	6.3
Aviation gasoline	1130	5.9

And, in the very low water periods, the tanker can be used and loaded according to the following draft readings:

5.5 feet	930 tons
4.6 feet	735 tons
4.1 feet	590 tons

Water depths of less than 4.2 or 4.3 feet will force curtailment of operation of the tanker since, when the tanker draws less than 4.1 feet the propellers do not operate satisfactorily.

Models are being built so that tests can be conducted to determine how the actual ship will act in both deep and shallow waters at various drafts, etc.

The nine man crew will be housed in single cabins in the after superstructure. The main propulsion machinery, two 400-hp R8DV-136 engines, is also located aft.

CZECHOSLOVAKIAN DIESEL ENGINES

The manufacture of diesel engines, of all types, including marine, is an important part of overall industrial production in Czechoslovakia and, in the past twenty years production of diesel engines has increased some 30 times. Over 70 per cent of this production is exported to 60 countries around the world. Soviet sources claim that Czechoslovakia is in fourth place in the world's diesel engine export market.

Today's production includes over 100 types of diesel engines ranging from 5 to 200 horsepower from plants which put their insignia on the engines in accordance with their names, i.e., Skoda, Slaviya, ChKD, Tatra, and others, names going back to pre-World War II days and retained today because of their fame throughout the world.

Representative engines with certain of their particulars, are:

Plant	Mark	EHP	RPM	Bore, inches	Stroke, inches
Skoda	6-8S-310DR	750-1000	750	12.1	14
Slaviya	D-5	5	900	3.9	4.9
ChKD	K8S-310DR	1650	720	12.1	14
Tatra	18T-955	300	2000	4.3	5.2

DKRN 74/160 MARINE DIESEL

Recently available information indicates that the Bryansk Diesel Works has been in the process of manufacturing, under license, the Burmeister-Wain 74-VTBF-160 engine (see the JOURNAL, February 1961, p. 77) under the designation DKRN 74/160.

The Soviet versions, initially, will be 7-cylinder models for use in a new type of cargo ship as main propulsion. With a bore of 29 inches and a stroke of 62½ inches the engine will develop 1250 horsepower per cylinder at 115 rpm. The argument in favor of undertaking the construction of such engines is taken from the fact that diesel engines are the most economical types of main propulsion at the present time, statistically backed up by figures showing that 40 per cent of world ship construction will use such engines and, if tankers are taken as a separate category, the percentage is even higher.

The ship which is to use the new engine has been tentatively projected as follows:

Length overall, feet	510
Length between perpendiculars, feet	460
Beam, greatest, feet	67

Height of side, amidships, feet	40
Draft with general cargo, feet	25
Deadweight, tons	8000-12000
Main propulsion, horsepower	8750
Speed, knots	17
Cruising radius, miles	10000
Endurance, days	40

This single-shaft ship is to have the machinery aft and all machinery in the engine room will, with the exception of the boiler feed pump, be electrically driven from a 380 volt alternating current power net.

The curious fact about this whole project is that, despite advances made in various fields of technology, diesel engine building is not included. In fact, Engineer A. Ya. Markov points out that the Danish engine was selected because the Soviet merchant marine must be provided with new, economical main engines, none of which, apparently, are available from original designs built within the Soviet Union.

THE VOLGA RIVER

The Volga River complex accounts for over one-third of all cargo transported on the rivers in the Soviet Union. The burden for this performance falls on the two major river lines in the Ministry for the River Fleet, the Volga Combined Steamship Line and the Volga Tanker Steamship Line, the latter specializing in transporting petroleum products.

As usual, reports on operations of the two lines are mixed. For example, while the Volga Combined SS Line was patted on the back for its work in the 1960 season, the result of having crews on 455 of its motorships work in two capacities, it also was charged with having cost the state a considerable amount of money for casualties incurred. The combining of jobs on the ships released 1500 qualified workers for tranfers to other ships, presumably new ones, and the overall result was a reduction of 3 million rubles in the bill for crew maintenance for the year. This saving, however, was off-set somewhat by the 1.5 million loss resulting from casualties.

Causes of the casualties included violation of the rules of the road, negligence on the part of personnel on watch, drunkenness. Disciplinary action was taken against 200 workers at the command, or officer, level as a result of an attitude which considers casualties to be an inevitable result of intensive operations, an attitude frowned upon by the Ministry but one which continues to hamper operations.

The situation in the Volga Tanker SS Line was similar. On the plus side of the ledger was the report that the line had turned in some 13 million rubles more than had been anticipated in the planning for the season's work. Not one ship type met its plan, however, and the tankers, most important of the ship types, racked up a production figure of but 86 percent of plan. The fleet was charged with a loss of 13 million ton-days in demurrage for the season and what success there was was explained by the fact that the state has provided what amounts to a surplus of tonnage.

Despite this, we note that construction continues and Stalingrad Shipyard is coming out with the largest river tanker yet, one of 5000 tons capacity. The latest in the line of river tankers will be over 425 feet in length and will draw about 11 feet of water. Designed to make 10-knots, using a propulsion plant of two 1000 horsepower diesel engines, the new tanker will carry a crew of 15 and will be used on the Volga, Kama and Don rivers. It is believed that the vessel has been named *Khasan.*

Some changes in the line's administration may be forthcoming in view of the charge that, in 1960, ships assigned to the tanker line suffered a considerable amount of damage, 39 percent of which came as a result of groundings and 42 percent from collisions. In this line, in contrast to the Volga Combined, attempts to get personnel to take on more than one job did not even start until 1959, whereas the idea originated and was put into practice in most of the other lines in 1950.

All of which caused the Collegium of the Ministry for the River Fleet to charge the line with being a bottleneck in the Ministry's attempts to meet its quotas and indices. The process of transporting petroleum products has come in for criticism because labor productivity in the Volga Tanker has fallen 6.5 percent over the past five years, although wages are said to be up 13 percent over the same period. Too, the line has done little to encourage shippers of petroleum products to make use of water transportation. This charge is substantiated by pointing out that products move to Cherepovets by rail, very little product moves into Moscow by water and products rarely move via the Volga-Don Canal.

ARCTIC TRANSFER—1961

The Expedition for the Special Transfer of River Ship is preparing for the 1961 transfer via the Northern Sea Route under the leadership of F. V. Nayanov. He has dispatched crews to pick up ships in Arkhangelsk, Leningrad, Izmail, Kherson and other ports. Work is also going on to strengthen those ships which are ready, and most of those to move over the Route this year are scheduled for the rivers in eastern Siberia. Most of the new ships being readied to start across the Black and Azov seas are in Izmail, Kiliya, and Kherson. In Izmail are the 3-decked passenger ships *Sverdlov* and *Zhdanov,* with the Hungarian-built 2-decked passenger motorship *Akhtuba* coming, as is the 1000 hosepower cargo motorship *Aksay,* built in Rumania. Another caravan has moved from East Germany to Leningrad and included the 3-decked passenger motorship *General Vatutin* and *Vilgelm Pik* and two 400 horsepower tugs. These are the first of some one hundred new passenger and cargo motorships,

tugs and dredgers scheduled to move out of Leningrad this year.

SHIPBUILDING IN CHINA

The recent announcement in our press concerning the growing strength of the Red Chinese submarine fleet in the Pacific caused some concern among those who must cope with the problem, and rightly so, for Red China is on her way to becoming one of the larger shipbuilding countries in the area.

The naval building program, aided and financed in large measure by the Soviet Union, is an offshoot of the river and maritime building program which started some ten years ago. Progress has been considerable, as we shall see.

The modern industry is founded on reconstructed and expanded shipyards concentrated in the Shanghai area, as well as other yards along the coast. It is claimed that in the 100-year period up to 1949 the total output of Chinese shipyards was some 500,000 tons and that 94 percent of all tonnage afloat on the rivers was built of wood, powered by sail.

In 1953 work was undertaken to rehabilitate existing facilities and expand them to build large ships for use in coastal trade, as well as in foreign commerce. During this period China was dependent on the Soviet Union and Poland for overseas communications, with certain of the Western nations maintaining regular runs in and out of Chinese ports. Although China is hardly self-sufficient at this time, some progress in building for her own needs has been made.

Progress also included the establishment of scientific and research organizations, a planning and design bureau, shipbuilding institutes, technical schools and vocational schools, all designed to provide the personnel needed for the burgeoning industry. Soviet, and other, products went into the outfitting of the yards and were used to build the longitudinal and transverse ways on which the ships were to be built. Machine shops were built as well and it is claimed that these shops can build some of the marine engines being installed in Chinese-built ships. Smaller yards, building small and medium sized ships, have either been reconstructed or built in the most important areas of maritime and river activity, as well as in areas where fishing is an important industry. A model basin was started in 1950, and completed in 1954. It is said that all the work of construction and outfitting, including the design and manufacture of the experimental electronic controls and measuring instruments, was done by Chinese workers and engineers. Later on the construction of a cavitation tunnel, a wind tunnel and an open model basin was begun. Research and experimentation has been done on the development of shipbuilding materials, electrical installations and instruments, marine installations and shipbuilding engineering.

Officially it is claimed that by 1959 the tonnage of the ships included in the transportation and industrial fleets has more than doubled the 1950 figure. On 1 November 1959 the merchant marine of Red China included 172 ships (300 GRT and over) with a total registered tonnage of 427,000 and a total deadweight of 571,000 tons. Ship production in recent years has been:

Year	Tons, DW
1957	54,000
1958	90,000
1959	122,000

In 1950-51 the yards produced tugs and barges for use on the rivers and lakes, but in the past ten years this production has grown to include dry-cargo ships capable of carrying 50, 3000 and 5000 tons, coastal passenger ships which can carry 50, 200 and 500 passengers, river cargo ships of 1000 and 1800 tons capacity, river passenger ships carrying as many as 1000 passengers, tugs ranging in horsepower, from 40 to 2000, fishing vessels equipped with engines of from 75 to 350 horsepower, refrigerator ships and special types, including dredgers, floating electrical stations, icebreakers for use in the lower courses of the Yangtze River, and rail ferries. Today production has been expanded to include naval vessels, including the submarines already noted, and 10,000 ton dry cargo ships and a hydrofoil for use on the Yangtze River.

Engine building has been expanded to include production of steam engines rated at 1500 and 2400 horsepower and marine diesels rated at from 5 to 900 horsepower. An experimental engine of 2000, and another of 3000, horsepower were started in 1958. Preliminary trials appear to have been successful, but further research and modernization is indicated. An 8820 horsepower diesel, for use in the 10,000 ton cargo carrier class already cited, was started in the Khudun Yard in Shanghai at the end of 1959. Only one cylinder was built and tests of the model will determine the ultimate results of this program.

Finally, steam turbines have gone into Chinese built ships in the form of the 500 horsepower unit used in the 6000 ton capacity dry cargo carrier. The engine is said to have been the product of Chinese design and manufacture. Engineers are said to have completed the design of a steam turbine of higher efficiency as well as that of a gas turbine.

Steel for shipbuilding, once imported from abroad, is now usually manufactured within China and welding is widely used in all yards, including fully and semi-automatic types of welding. Modern techniques such as the latter have assisted in bringing down the time taken to build the various classes of ships, usually planned in groups of 50 units.

In 1950 it took 150 days to complete the design of a 50 ton capacity cargo ship, and an additional 207 days to build it, a 2000 ton capacity river barge was in the design state for 120 days and under construction for 202 days. In 1958 the Kiangnan

(Tszyannan) Shipyard took 90 days to work up the plans for a 5000 ton capacity coastal cargo ship and then built the ship in 162 days. Construction time for a 250 horsepower fishing vessel was 300 days in 1954, but in 1958 the same ship was building in the Chusin (Tsyusin) Shipyard and took but 82 days to construct. The Chunhua (Chzhunkhua) Shipyard, in 1957, took 11 months from design to underway trials for an icebreaker assigned to the Yellow River. However, the way time for the second of the 5000 ton capacity cargo ships built in Kiangnan was but 35 days and, in the Hungtung (Khudun) Shipyard the way time for a 3000 tonner has been reduced to 19 days.

Many small yards, formerly engaged in ship repair work, have started to build small ships. For example, the Nanking Shipyard has designed and built an 80 horsepower tug; the yard in Uchan has built a 500 horsepower tug; the yard in Foochow a 300 horsepower tug; and the Chunhuaban (Chzhankhuaban) Shipyard 280 horsepower fishing craft. Small plants, previously producing only negligible quantities of completed products, and which, usually devoted most of their capacity to repair of machinery, now are manufacturing marine diesel engines and gasoline engines of medium and small power. This is the case particularly in Hankow, Chansha and Harbin.

SHIPBUILDING IN POLAND

Some idea of the expansion which has taken place in the size of the Polish merchant marine, as well as in Poland's shipbuilding industry, can be obtained from the announcement that in 1935 the Polish merchant marine totalled 73,000 deadweight tons of shipping. On 30 November 1960 the total was 871,988 deadweight tons:

DWT	Number of Ships	Total DWT
10000 up	44	482,305
8001-10000	14	128,968
6001-8000	5	33,668
4001-6000	14	69,520
3001-4000	19	61,827
2001-3000	10	25,404
1001-2000	17	23,122
up to 1000	142	47,174
Total	265	871,988

Reports have indicated that as many as 60 merchant ships flying the Polish flag have been on the high seas at once, enroute to Africa, India, the Far East, as well as to this and other continents.

Virtually all of the new construction has come out of the Gdynia-Gdansk area on the Baltic coast. The Paris Commune Shipyard in Gdynia is building an 820-foot long dry dock which will be ready for use in 1962. It is claimed that this installation will permit the shipbuilders to cut the building time for the 10,000 ton displacement cargo ship from its present 5-6 months to 2.5 months, increasing the yard's production capability to a figure of .68 tons per square foot of yard area, said to be one of the highest in Europe.

Poland exports ships to the Soviet Union, Communist China, Czechoslovakia, Indonesia, the UAR, Brazil, and other countries. Polish yards are said to have orders for 2 million tons of ships on their books, enough to provide them with all the work they can handle through 1965. Part of the order, and indicative of the part the Soviet Union plays in the economies of the captive nations, involves the building of 120 ships for the Soviet Union, this but a part of the new, long-term trade agreement between the two nations.

SHIPBUILDING IN BULGARIA

The Georgiy Dimitrov Shipbuilding and Ship Repair Yard, located in Varna, was founded 54 years ago and, in the past seven years has been completely reconstructed. Soviet assistance has been instrumental in converting this yard into a modern enterprise, useful to the Soviet Union both as a supplier of new construction and as a repair base for its merchant and naval vessels. The dry dock in Varna was built with Soviet help five years ago and, since that time, has repaired over 200 Bulgarian and Soviet ships.

Today the yard is building ships for Czechoslovakia, Albania, North Korea and other countries, as well as for the Soviet Union, using all-welded construction and the block and sectional methods of assembly. Until recently such construction has been limited to 3200 ton cargo ships, but, with the launching of *Alma Ata*, a 4000 ton capacity shallow draft tanker, for the Soviet Union, Bulgaria took over the type building program, evidently releasing capacity within the Soviet Union to build the cotton-timber carrier class now entering service on the Caspian. In fact, delivery of the new tankers to ports on the Black Sea permits their use in the periods when weather does not make it possible to move the ships from the Black Sea to the Caspian via the Volga-Don Canal.

Other production includes reinforced-concrete ships, one of which has been delivered to the Karl Marks Repair-Operations Base on the Volga River; in the planning stages is a passenger steamer for 100 passengers, ten of which are scheduled for delivery, as well as a fish factory-refrigerator ship. For the future, plans include a 500 ton capacity cargo ship with machinery aft, as well as an ambitiously hopeful program of 10,000 tonners.

SHIPBUILDING IN RUMANIA

According to a trade agreement between Rumania and the Soviet Union, Rumanian shipyards are to furnish the latter with 14 merchant ships between now and 1965. Rumania has been building merchant ships in the 4500 ton capacity class, such as *Iasi*, for her own use, but has been delivering tugs to the Soviet Union. One such, *Shilkovka*, was picked up in Galats by a Soviet crew sent all the way from the Kama River and, after delivery, was taken back via the Danube, Black Sea, Volga-Don Canal, Volga River system to the Kama.

"THE SHIPBUILDER AND MARINE-ENGINE BUILDER"

"MOSKVA"

A 22,000-S.H.P. DIESEL-ELECTRIC ICE-BREAKER

ACKNOWLEDGMENT

Reprinted from the December 1960 issue of the "Shipbuilder and Marine Engine Builder."

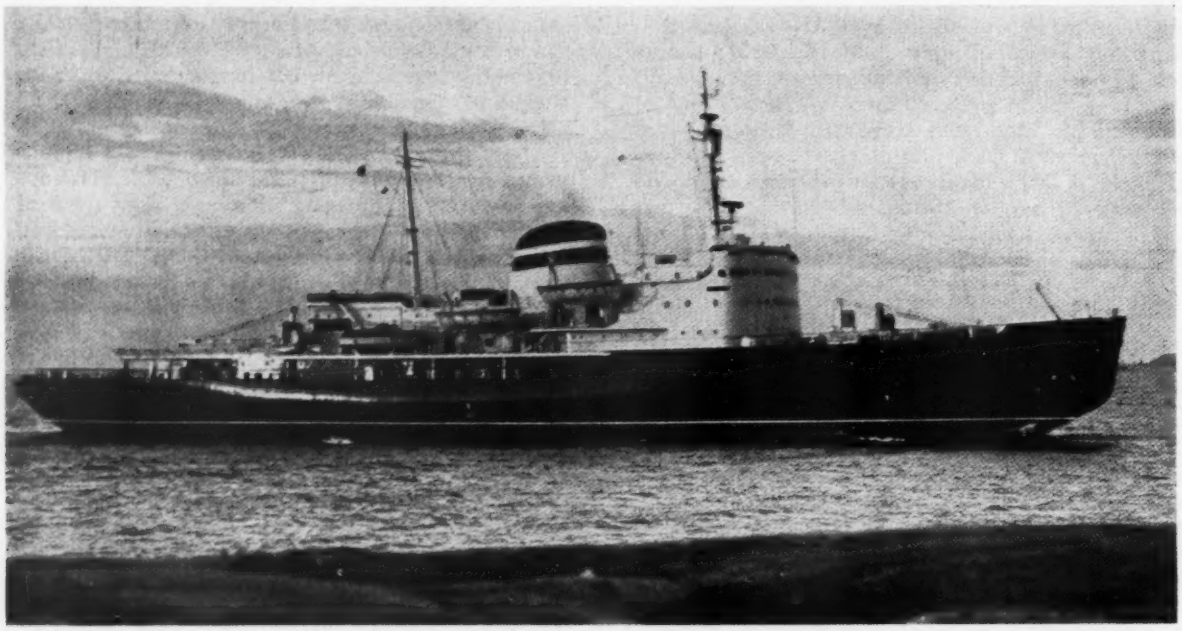
INTENDED for service in the Polar regions north of Siberia, where they will help to extend the shipping season for North Siberian ports, two powerful Diesel-electric ice-breakers have been constructed by the Finnish shipbuilders Wärtsilä-koncernen A/B., Sandvikens Skepsdocka. The order was placed by the Russian agency V/O Sudoimport, of Moscow, and the ships have been named *Moskva* (or *Mochba*) and *Leningrad*. For the purpose of this article we intend to describe the *Moskva*, which is portrayed above and referred to in Table I.

The shipbuilders have had to solve a number of technical problems during the construction. Because of the great hull weight on a comparatively short length and the fine lines of the afterbody, a special steel pontoon had to be attached to the stern in order to decrease the way end pressure.

The hull form is developed both for good ice-breaking qualities and strength. The shell is designed to withstand both the forces suffered during the passage through ice and those caused by the pressure of drifting ice masses. The strength is well in excess of the requirements of Lloyd's Register of Shipping, class ✣ 100 A.1 "strengthened for navigation in ice," and the Finnish ice class 1 A.

Completely welded, the hull is mostly (for instance, the whole shell plating) made of special steel with high impact strength even at low temperatures. The transverse bulkheads are fairly closely spaced and the frame spacing is 15¾ in. There are also deep, 4 ft. 11 in., webs at every fourth to sixth frame, as well as heavy longitudinal stringers, which, together with the frames, form a tight network of members. This is covered by the shell plating which, in the ice strake, has a maximum thickness of 2.12 in. Furthermore, all bulkheads, frames and deck beams forward and aft are placed transversely to the shell plating. The double bottom height is 5 ft. 11 in., and all floors are of the solid type and fitted with welded stiffeners.

The hull is equipped with an extended forecastle reaching well abaft the front bulkhead and a heavy superstructure ending aft with a helicopter hangar. Three continuous decks extend from stem to stern and the hull is divided into nine watertight compartments. As the hull is fitted with wing tanks, it is actually double up to the 'tween deck, well above the water line. It may be seen from the general-arrangement drawing reproduced in Fig. 2 that there are two propelling engine rooms, two Diesel-engine



rooms, refrigerated stores, provision stores, etc. The capacity of the double bottom, wing, peak and deep tanks is sufficient for 3,200 tons of Diesel oil, 290 tons of boiler fuel, 130 tons of lubricating oil, 350 tons of fresh water, and 20 tons of helicopter fuel. There are, however, spare tanks which allow a maximum bunker capacity of 5,300 tons if needed. In accordance with modern practice in ice-breaker construction, the vessel is also fitted with heeling tanks. For an explanation of this we would refer readers to the article entitled "Modern Ice-breakers," which appeared in the June Number, 1960, of *The Shipbuilder and Marine Engine-builder*. Four pumps transfer 480 tons of water from one side to the other in 120 seconds, resulting in a heeling angle of about 14 deg. The pumps can be automatically operated, resulting in a continuous movement of the vessel which is of extreme importance when caught in heavy ice pressure.

The nine bulkheads have, altogether, 16 watertight sliding doors which can be maneuvered on the spot, both manually and electrically, as well as manually from the deck above and electrically from the wheelhouse.

There is a fire-detecting system with about 300 points connected to an alarm table in the wheelhouse. Fire-extinguishing systems are provided for water, foam and CO_2.

Generally speaking the vessel is built to conform to Method III. of the International Convention for passenger vessels, employing *A* and *B*-class fire-resistant or fire-retarding bulkheads. Ventilation ducts passing through *A*-class bulkheads are fitted with pneumatically-operated dampers. In case of fire the entire ventilation system can be shut down and the dampers closed from the wheelhouse.

Principal Dimensions and other Leading Characteristics of the "Moskva"

Length overall	400ft. 7in.
Length B.P.	368ft. 9½in.
Breadth Moulded	80ft. 4½in.
Draught	34ft. 5½in.
Maximum displacement, metric tons	15,360
S.H.P.	22,000
Speed in open water, knots	18
Number of screws	3

The ice-breaker is heavily insulated, being intended for operation at temperatures around −35 deg. C. (−31 deg. F.). All the living quarters are heated by warm-water radiators calculated to maintain an inner temperature of +20 deg. C. (+68 deg. F.) at the aforementioned outer temperature. The mechanical ventilation system supplies preheated and filtered air to all parts of the ship to maintain a normal inner temperature in the living quarters, without the aid of any radiators, down to −10 deg. C. (+14 deg. F.) outside temperature. In this case, however, 50 per cent recirculation of the air is allowed.

ACCOMMODATION

Cabins, of officer type, are provided for 50 persons. This figure includes 30 ship's officers, a research team of nine, six air pilots and mechanics, as well as a doctor. The petty officers are accommodated in single-berth cabins, while the 48 seamen are housed in two-berth cabins.

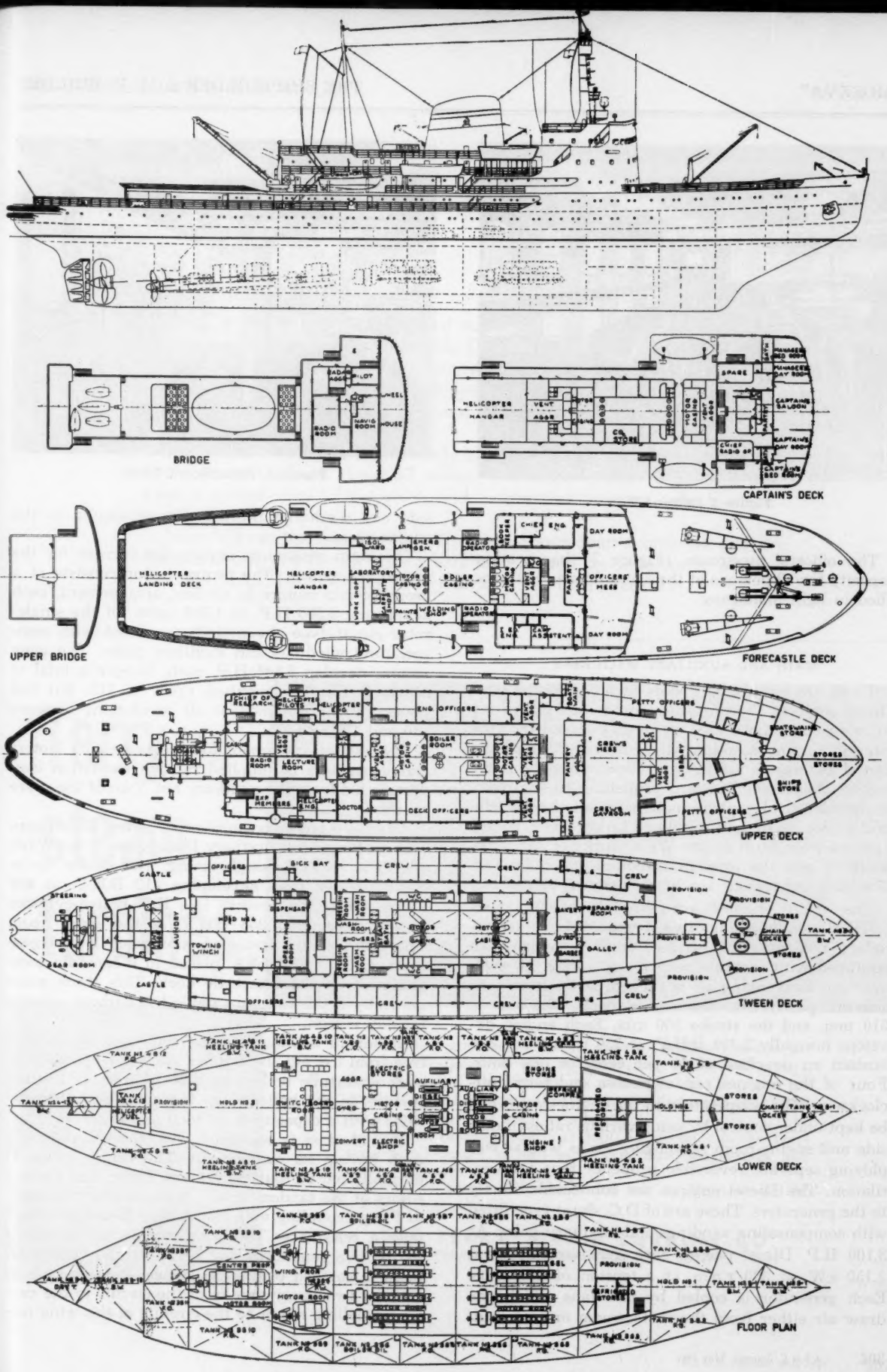


Figure 2. General Arrangement of the *Moskva*.

Figure 3. Officers' Mess.

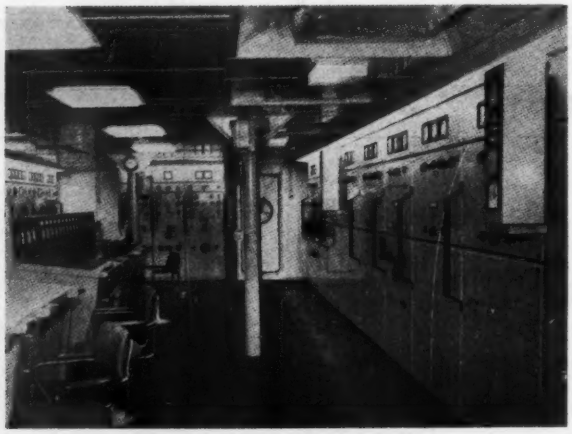


Figure 4. Switchboard Room.

The officers' messroom (Figure 3) has seating capacity for 40 persons at the same time and is panelled in light mahogany.

MAIN AND AUXILIARY MACHINERY

There are two engine-rooms each containing four Diesel engines. The propelling motors are placed aft in two rooms, the centre motor in one and the two wing motors in the other, while the seven auxiliary Diesel generators are in two rooms above the main engine. Above the forward propelling engine-room is the electrical control room with all the switchboards for main and auxiliary power. The Diesel engines were built at the Wasa works of the shipbuilders, and the propelling motors and main and auxiliary generators are of Siemens' manufacture.

The main engines are Wärtsilä-Sulzer, type-9.MH.51, single-acting, two-stroke cycle, nine-cylinder, non-reversible trunk engines which are equipped with separate scavenging pumps for each cylinder. Scavenging air is sucked partly from outside and partly from the engine-rooms. The bore is 510 mm. and the stroke 550 mm. Each engine develops normally 3,250 B.H.P. at 330 r.p.m., but can sustain an overload of 10 per cent for one hour. Four of the engines run clockwise and four anticlockwise. The temperature in the engine-rooms can be kept under control by using various ratios of outside and engine-room scavenging air as well as employing separate reversible propeller fans for ventilation. The Diesel engines are connected directly to the generators. These are of D.C. shunt type fitted with compensating windings and auxiliary poles. At 3,100 H.P. Diesel power, each generator develops 2,150 kW. at 330 r.p.m. at a tension of 600 volts. Each generator is cooled by two fans which can draw air either from the motor-room or from outside and discharge through the generator to the engine-room.

The main generators supply the current for the propelling motors. The centre motor consists of a group of two motors in tandem arrangement, each developing 5,500 H.P. at 1,200 volts. Of the single-rotor shunt type the motors are fitted with compensating windings and auxiliary poles. The wing motors develop 5,500 H.P. each, to give a total of 22,000 S.H.P. The nominal r.p.m. is 115, but full power can be obtained at all revolutions between 110 and 150 r.p.m.

The excitation current for the propelling motors and generators is supplied by five excitation converters fed from the auxiliary net. Two of these are spares.

Auxiliary power is supplied by seven Diesel generators. Six of the auxiliary Diesels are of the Wärtsilä-Polar K.58.E, single-acting, two-stroke cycle, eight-cylinder type developing 412 B.H.P. at 600 r.p.m., while the seventh is a K.55.E five-cylinder engine developing 258 B.H.P. at the same r.p.m. There is also an air-cooled emergency Diesel generating set of 62.5 kVA. placed in a separate compartment on the forecastle deck. This starts automatically if the auxiliary net is left without current for any reason.

Steam for heating, keeping cooling water intakes free from ice, etc., is supplied by two Wärtsilä-Babcock watertube boilers each of 1,400 sq. ft. heating surface. In the boiler room there is also an evaporator with a capacity of 30 tons per day.

The *Moskva* is equipped with three screws aft, each having its own circuit. The centre motor is normally fed by four generators. These, and the two rotors of the tandem motor, are connected in series in Punga coupling with the voltage O-point earthed over a resistance. The wing motors are normally fed by two generators and here also the voltage O-point is earthed over a resistance. It is possible to connect two generators from the circuit to the centre propelling motor to the circuits of the wing mo-

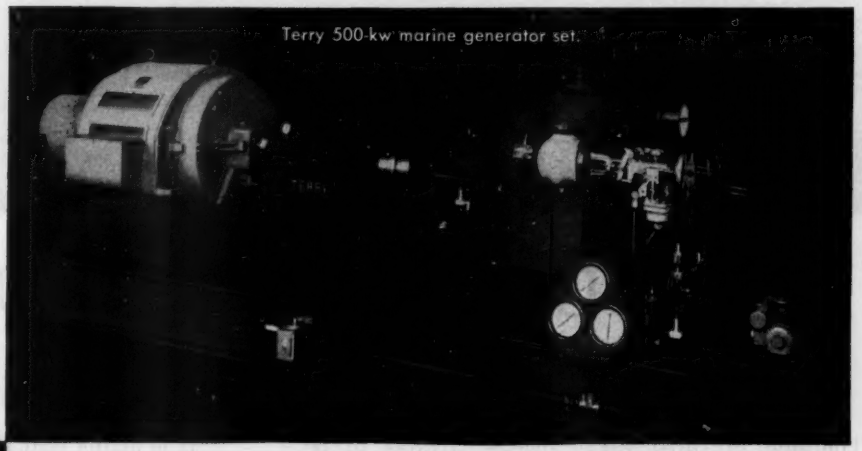
tors, as well as the reverse. Each propelling motor circuit is generally laid out according to the Leonard principle. The r.p.m. and direction of rotation of the screws is directly regulated from the maneuvering posts on the bridge. This takes place through regulation of the amperage and direction of the excitation current for the main generators. The main Diesels run with three constant numbers of revolutions which can be selected from the impressive switchboard room, which is shown in Figure 4.

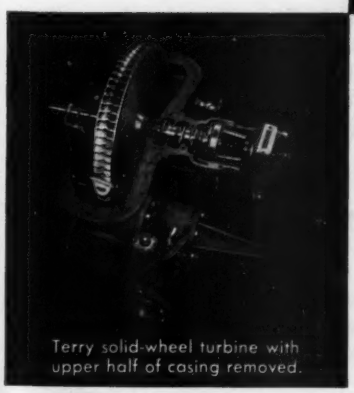
Navy is clearing the way toward construction of an all-aluminum submarine for oceanographic research. Dubbed the Aluminat, this sub will be built by Reynolds Metals Company and leased to the Navy. It will be 55 ft. long and 7 ft. dia., with a 6½-in. thick hull. Three to five persons could dive in the submarine to about 18,000 ft. and remain submerged for 36 hours.

The vessel will maneuver vertically and horizontally at approximately 5 knots. Its cost will run about $2 million; it will take a year to build. It will have a closed-circuit TV system, and mechanical arms to collect ocean samples.

Navy will use the Aluminat to learn more about deep submarine operations and detection, with strong emphasis placed on underwater acoustics. (PRODUCT ENGINEERING, February 27, 1961, Page 12)

Terry steam turbines


Terry 500-kw marine generator set.


Terry solid-wheel turbine with upper half of casing removed.

Dependable, compact, efficient . . . Terry marine turbines are specially designed for driving generators, boiler-feed pumps, fuel-oil pumps, compressors, etc., aboard ship. They are the result of over fifty years of experience in designing equipment for commercial and naval vessels.

Turbines ranging from 5 to 3000 hp are built in the Terry solid-wheel design as well as in axial-flow, single-stage and multi-stage types.

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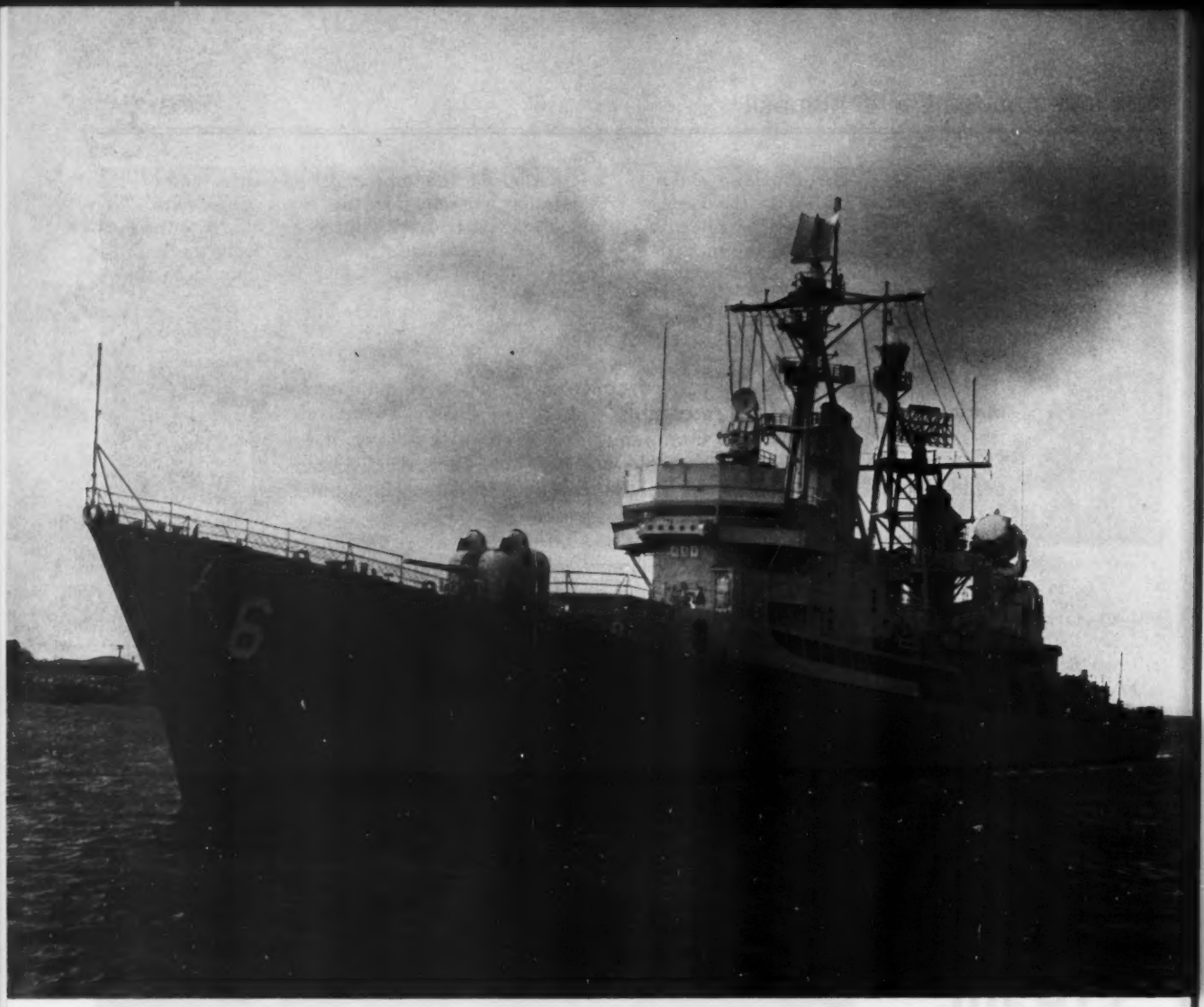

USS FARRAGUT
...new, guided-missile frigate

The first of three guided-missile frigates to be constructed by Bethlehem Steel Company's Quincy, Mass., shipyard, the USS Farragut (DLG-6), was delivered to the U. S. Navy on 8 December 1960.

Displacing approximately 5,600 tons, she is one of the most powerful anti-aircraft and anti-submarine weapons in our fleet. Her overall length: 512 ft 6 in.; beam: 52 ft 4 in.

It is fitting that this distinctive ship bears the name of one of the most colorful naval officers in our history . . . David Glasgow Farragut (1801-70) . . . who cut his eye-teeth as a cadet midshipman with Commodore David Porter in the War of 1812 . . . hero of the Civil War battles of New Orleans and Mobile Bay . . . the intrepid Admiral whose, "Damn the torpedoes! Go ahead!" is one of the proudest traditions of the United States Navy.

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RALPH A. MILLER

THE CENTENARY CELEBRATION OF THE ROYAL INSTITUTE OF NAVAL ARCHITECTS

EDITOR'S NOTE: *Following is Mr. Miller's condensation of the second paper which was presented at the Centenary Celebration of the Royal Institute of Naval Architects, at which he represented the American Society of Naval Engineers. Mr. Miller's report at this meeting and his condensation of the first paper presented, were published in the February 1961 issue of the* JOURNAL.

MERCHANT SHIPS 1860-1960

by J. M. MURRAY, M.B.E., B.Sc.

IN HIS INTRODUCTION, the Author mentions the difficulty of trying to encompass within the confines of one Paper the developments in Merchant Ship design and construction during the past century. To alleviate the task somewhat, he confines himself generally to British practice because such information is more readily available. The ships are divided into two classes: cargo ships and passenger ships. He considers the North Atlantic passenger liner to represent in some measure the most important product of the naval architect and marine engineer. In examining the development of the dry cargo ship, the Author has taken the technical progress of a well known line of cargo ships, as data, for the ships of this line were available for the past century to a greater extent than usual, and because the present standard represents a very advanced design.

Steam propelled iron ships were well established a century ago. By 1870, 30 percent of the tonnage being built in the United Kingdom was of iron, and 66 percent was propelled by steam. The opening of the Suez Canal in 1869 gave impetus to the building of steamships and the increased economy resulting from the development of the compound engine at this time, established the steamship in the Far East trade, causing the gradual elimination of the sailing ship. The design of cargo ships then became stable, in the broadest sense, for a long time, due largely to the continued strength of British coal export, which reached its peak in 1913, but has since dwindled so much as to be negligible now.

With the advent of reliable steel, steel began to rapidly replace iron. By 1890, 21 per cent of the world's ships over 100 gross tons, and 30 per cent of the gross tonnage, were of steel. By 1920, these

figures are 88 per cent and 96 per cent respectively, By 1959, these figures become 99.4 per cent and 99.95 per cent respectively.

When oil was struck in Pennsylvania, U.S.A., in 1859, no one realized the tremendous impact upon ship design that would result. Oil was first carried at sea in small containers, but, by 1885, the basic design of the oil tanker as we know it today, had developed. A revolution in marine propulsion started early in the twentieth century, by the developments of steam turbines and Diesel engines. As we pass the mid-twentieth century, nuclear fuel is in use to propel ships.

The Author states that none of the developments in ship construction did more than start a new technique, which gradually became popular if it had outstanding merit; there having never been with ships a new machine or method of construction, however outstanding, which, on its introduction, has rendered everything else obsolete, and that atomic power is not likely to be an exception. The composition of the world's fleets must change slowly, as owners can not afford to scrap existing ships for a slightly better design, and must in any event proceed with caution until a new device has been made reliable, and proven so in service. Charts and tables show variation in tonnage launched in the United Kingdom during the past century, the composition of the merchant fleet for 1900 and 1958 by age groups, and fluctuation in costs.

The Author divides his Paper into two parts, one dealing in a general way with progress in ship design and structure, and the other with matters of safety, speed and materials.

The Author starts the first section by noting the scarcity of information of a particular nature regarding early iron and steel merchant ships, although much general data are available in the Transactions of the Royal Institution of Naval Architects and other sources. He states data relating to the first half of the period covered by the survey are rather sparse, and probably not too reliable; but that later matters improve and now there is a wealth of accurate data.

The development of cargo ships during the century is considered, in general, to be in three equal periods,—initial improvement, stability, and rapid progress which may well extend into the future.

The cargo ships of the 1860's and 1870's closely followed the design of sailing ships. The evolution from flush decks to short bridges, forecastles, poops, raised quarter decks, well decks, three island, awning decks, shelter decks, spar decks, etc. is traced. The development of the turret design in 1892 and the trunk design in 1896 is discussed. The self-trimmer was developed about the turn of the century. It has survived, whereas the turret and trunk design have vanished. Sketches of amidship sections of various designs are shown.

At the turn of the century, much attention was given to designing ships with low net tonnage. The ratio of the deadweight to net tonnage was considered an important criterion of the ship's efficiency.

For at least 25 years preceding World War I, there was but little change in the general character of cargo ships and their machinery. The typical steamer still burned coal, 99.6 of the tonnage burning coal in 1914.

Large numbers of cargo ships were built to several standard designs during World Wars I and II. All of the standard World War I designs had triple expansion engines, Scotch boilers and burned coal. The standard World War II cargo ship was generally similiar to the World War I design, but the cargo liner of World War II showed great improvement, having geared turbines and water-tube boilers burning oil.

The general cargo ship has given way to specialized designs, and size and speed have increased. At one end of the specialized designs is the "container" ship, and the "roll-on, roll-off" ship. At the other extreme is the bulk carrier with machinery aft.

The merits and demerits of placing machinery aft or amidships is discussed. A compromise arrangement of placing the machinery about half-way between the amidships and aft positions is becoming increasingly popular. The Author considers, however, that the future seems to lie with the machinery aft in bulk carriers.

The Author states that the growth in size and speed of dry cargo ships over the years is a natural phenomenon, and as such is worth some consideration. Size has not increased because of any important developments in materials, as mild steel has been the material used throughout the period, mild steel being adequate for the larger dry cargo ships. Reference is made to a Paper by Tutin, read before The Institution of Naval Architects in 1922, "The Economic Efficiency of Merchant Ships," wherein it was shown that, unless trade conditions caused a ship to run at a loss, increase of size will result in an increase in interest on the investment. The effect of harbor limitations are discussed. Port and harbor authorities have realized the pressure demanding increased size of ships, and have gradually increased the size of berth facilities; for instance the River Clyde maintenance depth increasing from about 15 ft in 1871 to 27 ft in 1957. A table is given showing the average sizes of cargo ships between 1870 and 1937. This table shows that the length increased an average of about 3½ ft a year between 1870 and 1920, when the length became about constant at about 405 feet. Charts are shown giving the percentage of dry cargo ships of 400 feet length and over, and speeds of 10 knots and over, for the years 1946, 1952, and 1958. The Author notes that the large cargo ship of 15 years ago is the average cargo ship of today.

Between about 1860-1880, ships were relatively narrow by today's standard, having an L/B of about 10. This ratio was not changed when erections were added to the flush deck design, and the fitting of double bottoms raised the C.G. of cargoes. A very unsafe type of ship resulted, and losses due to lack of stability were severe, particularly in the North Atlantic grain trade in the 1870's. Charts show the proportions between 1860 and 1900. With an L/B of 10 plus zero in 1860, the average beam increased to about L/B of 10 plus 12½ feet in 1900, and an L/B of about 10 plus 17.2 in 1958. The B/D remained about constant from 1860 to 1875 at about 1.26, then rose to about 1.9 at 1900 for full scantling and part awning deck ships. The B/D for three-deck and spar deck ships remained about constant until 1875 at about 1.34, and then increased to about 1.66 by 1900. During World War I this ratio was 1.67 for three island ships, and 1.9 for shelter deck ships, and was 1.95 for shelter deck ships in World War II.

The Author lists four reasons, "two rational and two less so, but equally powerful, for the increase of speed over the century": the increase in ship size made increased speed appropriate; the use of a more efficient fuel-oil; the increased pace of other means of transportation and of life generally; and fashion. The Author surmises that the two latter forces cause speeds of cargo ships to probably be greater than necessary. To show that the increased tempo of life is not new, the Author quotes from an article of 1884, which states, "In these days of feverish activity in every avenue of business even when leisure has come to be observed at a much more accelerated tempo than formerly, speed in locomotion would seem to be the first consideration not only on shore but afloat as well."

The Author considers that the best speed can be defined more closely than the best size, although they are inter-related. Speed is considered more important in scheduled ships than in tramps, and assessing the optimum speed for the former is harder than for the latter. Trade-route conditions may sometimes over-ride theoretical considerations. Greater speeds are generally justified for longer voyages.

The term "economical speed" may have three definitions: (a) the speed at which the ton-mile cost is least; (b) the speed showing the greatest yearly profit, i.e., the greatest difference between income and expenditure, and (c) the speed giving highest interest rate on money invested. The critical speed may be taken as the point on the power curve where a distinct change in slope occurs. This point is fairly close to that obtained from (a). The increased speed from 1870 to 1937 are shown to be largely that suitable to the increased length, as the average speed-length ratios varied from 0.50 in 1870 to 0.51 in 1937, with highest of 0.57 and lowest of 0.49 between these years. Dry cargo ships over 400 feet long showed average speed-length ratios of 0.66, 0.70 and 0.64 for 1946, 1952 and 1958 respectively.

Block coefficients were fine a century ago, probably due to sailing ship influence. Its value had increased from 0.72 to 0.80 at the turn of the century, but was down to 0.74 by 1937, but have been again increasing, particularly at the lower speeds. The Ayre adaption of Alexander's formula, "Block Coefficient $= 1.08 - \frac{V}{2\sqrt{L}}$" is an attempt to determine the largest suitable value for a given speed. This formula gives values of 0.887 and 0.63 for speed-length ratios of 0.40 and 0.90 respectively. The average values for ships over 400 feet long built in 1946, 1952 and 1958 were: 0.79 and 0.63, 0.81 and 0.63, and 0.87 and 0.62 respectively, at these speed-length ratios. Thus, present block coefficients closely agree with the Ayre-Alexander formula.

The importance of cargo handling is discussed, inasmuch as port time amounts to 40 per cent or more for average general dry cargo ships. A study has shown that, should improved design result in a sea-speed increase of 25 per cent without increased fuel cost or capital invested, the same results could be had, could port time be reduced 25 per cent. The problem is not new, and was discussed by the Royal Institution of Naval Architects as early as 1884. There have been many studies in recent years regarding improved cargo handling. The Author states "from these it appears that while substantial improvements can be effected by the use of modern types of lifting appliances the really difficult problem is the human one." Apart from highest efficiency cargo gear, the main needs are: hatchways as large as practicable, placed so that the average horizontal cargo movement is as small as practicable: hatch area ratio to hold area should be constant for the ship for uniform working speeds; and holds should be free of internal obstructions, such as lower decks.

Three interdependent considerations have influenced ships' structures; that of providing clear holds for carrying and working cargo by eliminating internal obstructions; that of weight reductions by most efficiently placing material; and that of ensuring a hull sufficiently strong to meet the sea forces. Scantling changes between 1871 and 1947 are shown by midship sections of ships built in this period, with accompanying midship sections of the same ships having scantlings to Lloyd's current Rules. The reductions in continuous metal is shown to be as much as 22 per cent on the older, shorter ships.

There has been much effort to develop holds without pillars. A satisfactory design has resulted, wherein the double bottom depth was increased and bilges suitably framed.

The electric welding of hulls continues to increase. The amount of welded structure in dry cargo ships over 400 feet long, classed with Lloyd's, is estimated as 0.71, 0.73 and 0.77 for 1956, 1957 and 1958, respectively. Oil tankers are about 0.90 welded.

Illustrating the generally known fact that ship classification societies' Rules are based upon service experience, the Author describes some failures and their remedies, including damaged deckhouses, buckled decks and the corrugation of the bottoms of all-welded ships. These difficulties have been overcome by the almost universal adoption of longitudinally framed decks and bottoms of cargo ships.

As the standard of living accommodations ashore have risen in the past century, so have the standards afloat, and partly because a better class of men is going to sea. From 1850 to 1900, at least 22 sq.ft/man was required for combined berthing and messing spaces, with 2 sq.ft/man for baths and sanitation. By 1959 89 sq.ft/man was required for sleeping space only, with 28 sq.ft/man for messing space, and 11 sq.ft/man for baths and sanitation. Whereas large numbers were formerly berthed in one space, not more than four men are now allowed in one room. Some progressive owners fit a single room for each member of the crew. The fitting of electric plants has greatly increased the comfort and well-being of the crew.

The Author notes that the origin and history of ore carriers has attracted less attention than has the development of oil tankers, and remedies this state in some measure. There are now probably some 4,000,000 gross tons of this distinctive type of ship afloat. The large bulk ore carriers were first developed on the American Great Lakes, where large single deckers were used by the turn of the century. The deep-sea transport of ore started in 1903, when *Upland* loaded ore at Narvik. The first deep-sea ships designed for carrying ore were turret deck ships delivered in 1904. *Polcirkeln*, delivered in 1907, may be considered the prototype of modern ore carriers. The machinery was aft, and the ore holds were bounded by two longitudinal bulkheads and a double bottom.

Although grabs were used on the American Great Lakes for unloading ore, they were available in very few ports. As a result, two self-unloaders of 8000 and 10,800 tons deadweight were built in 1909 and 1910 respectively. The latter was considered then to be the largest single-deck ship in ocean trade. By 1922, the need to provide for return cargoes was realized, and ships were designed to carry either coal or oil on the return voyage. Due to the varying demands of the ore trade, some ships built in the 1930's were of the open/closed shelter deck type, and thus suitable for general cargo. Others were so arranged as to be convertible to standard tankers. The present phase of ore/oil carrier design and construction may be said to have started with the 12,100 deadweight *Rautas* (1944) and *Raunala* (1946). Size has gradually increased to the 56,000 deadweight ton *Petrolore*. Many features common to ore carriers, such as large hatches, clear holds and decks, and steel hatch covers, have been adopted by dry cargo ships, which are gradually assuming the characteristics of ore carriers in both design and size. Outlines of 'midship sections trace the development of ore carriers.

The discussion of oil tankers is rather brief, the Author stating that its history is unusually well documented. The first tanker having the basic design features of today, was built in 1886, having a deadweight of 1,650 tons, and a 10 knot speed. Today's large tanker is of 104,500 deadweight tons with 15.5 knot speed,—showing a remarkable growth in 75 years. Increased size has been gradual, but has quickened since World War II. The 1936-1938 tanker averaged 12,000 deadweight tons. By 1948 this was 14,000 tons, and 26,000 tons by 1958.

Exceptionally large tankers have been built at times during this 75 year period. A 12,850 deadweight ton tanker was built in 1916, and a 24,200 deadweight ton tanker was built in 1928. But 30 years were to elapse in each case before these extreme sizes became average.

Charts showing the various percentages of tankers of different sizes over 400 ft built to Lloyd's class in 1946, 1952 and 1958 are given. They show that 70 per cent of the 1946 tankers were of 13,000-15,000 deadweight tons; 85 per cent being of 16,000-22,000 deadweight tons in 1952, and 40 per cent being of 20,000-22,000 deadweight tons in 1958. What may be called "size-percentage groups" shows greatly increased diversity in tanker sizes, there being 7 such groups in 1946, 14 in 1952 and 25 in 1958.

The marked oil tanker growth clearly shows the effects of factors previously discussed. The oil tanker transport cost a ton-mile decreases in a somewhat exponential manner as size increases, the curve starting to flatten at about 60,000 tons, but continuing downward.

Normally, there is no economical justification for very high speeds, and, contrary to dry cargo ships, tanker speed-length ratios have not increased much in the last 30 years. Before World War II the "standard" 460 ft., 12,000 deadweight ton 12 knot tanker had a speed-length ratio of 0.55, but for tankers now building, it is between 0.60 and 0.70. Tankers over 400 ft long, built to Lloyd's Class in 1958 have block coefficients concentrated in a marked degree between 0.77 and 0.79.

Throughout the period under review, tankers have been remarkable for their uniformity of design. With slow speed, large machinery spaces are not needed, and tanks can be arranged to give proper trim, with but little variation with size. Regarding structural strength, this standardization in de-

sign and in method of operation permits a close relationship between the main longitudinal scantlings and the design features of the ship. Main factors affecting bending moment are: length of oil tanks relative to ship length, their longitudinal position, machinery weight, and block coefficient. A modern development is the fitting of certain void tanks near amidships, these reducing, bending moment and permitting lighter scantlings. This is compatible with the tendency to limit ballast to specific tanks to reduce internal corrosion. The proper placing of these void tanks is needed when the dry cargo hold is omitted. The Author expects continuance of the trend to place the bridge and all accommodations in the poop.

The Author closes the section on dry cargo ships with a review of six such ships developed by one line between 1870 and 1958. Deadweight increased from 3,330 tons to 10,926 and IHP from 370 to SHP of 15,000. (The ratio of actual power delivered to the shaft is somewhat greater than that indicated, as a number of pumps were generally driven by the main reciprocating engines, the power of which added to the friction losses that had to be deducted from the I.H.P. R.A.M.*). The compound engines of 1871 gave way to triple expansion engines by 1887, to quadruple expansion engines in 1922, and steam turbine by 1948. The overall machinery weight with reciprocating engines was nearly constant at about 0.23 tons/IHP. Turbine installations (presumably with watertube boilers) were 0.11 tons/S.H.P. in 1948, and 0.07 tons/S.H.P. in 1958. Block coefficients varied from 0.66 to 0.79 to 0.76, but had lowered to 0.67 in 1948, and 0.55 in 1958. The speed-length ratio was fairly constant, averaging about 0.58 until it became 0.74 in 1948 and 0.84 in 1958.

A tabulation of calculated hull girder stresses in waves of the ship's length and heights of $1.1\sqrt{L}$, gives values about equal to $\sqrt[3]{L}$ multiplied by 1.18 for 1871 ship, 1.22 for 1887 ship, 0.97 for 1900 ship, 1.31 for 1911 ship, and 1.17 for 1921 ship and 1948 ship. The high stresses in the 1911 ship resulted from the reduced scantlings permitted by the 1909 revisions to the Rules. Stresses were lowered when the Rules were revised in 1922. The Author states that the table seems to show basically that our ancestors, by intuition and common sense, had evolved a standard of scantlings, which, when examined in the light of decades of experience, was not widely different from that considered proper now. Drawings and photographs show the evolution of these ships from 1871 to 1958.

The 680 ft *Great Eastern* (1859) dwarfed early passenger ships, and her length was not exceeded until the 685 ft *Oceanic* (1899) was built. Due to competition betwen the large steamship lines, ships' size and speed increased, and the amenities constantly improved. Numerous improvements were made in the accommodations for passengers and crew, and in the appointments, lighting and ventilation of staterooms. Around the 1880's, the public rooms were moved from aft to amidships to lessen the effects of propeller vibration, and of pitching. Also 'tween deck heights below the deck beams rose from about 6 feet to as much as 9 feet, allowing better architectural and decorative treatment. Domes over the main saloon were introduced at this time, later extending two full deck-heights.

There have been continuous improvements from the modest comforts of the 1880's, culminating in the fitting of air conditioning and anti-rolling fins, though but little has been done to eliminate excessive pitching. The increase in passenger amenities can be roughly shown by the increased ratio of gross tons/passengers. A table shows this value to range from 4.7 for *Great Eastern* to 37.8 for *Queen Mary*. (The low ratios for the earlier ships seemingly resulted largely from the large numbers of emigrants then carried. R.A.M.)

The Author selected ships of the Cunard and White Star lines to illustrate the development of passenger service, and considers *Umbria* (1884) as the earliest ship that can be considered in the same category as the modern passenger liner. This 500 ft ship of 14,700 I.H.P. exhausted the potentialities of single screw large passenger ships, all later ones having two or more screws. *Umbria* had a potable water distiller, but they were not fitted to following ships. *Teutonic* (1890), twin screws, of 16,000 I.H.P. total showed considerable advance. She was unusual in that the propellers overlapped in a deadwood aperture, which was thought to have materially reduced the vibration from that of her sister *Majestic* having a more orthodox design. The 600 ft twin screw *Campania* (1893) and *Lucania* of 27,650 I.H.P. were magnificent ships. The dining saloon was 100 ft long and the beam of the ship (about 63 feet wide) lit by electric lights. The 1350 lights in the ship were supplied by a 42 KW generator. (Marconi conducted wireless experiments on *Lucania* in 1901, and in 1903, *Lucania* was the first ship to publish a daily newspaper with news received by wireless. R.A.M.)

Lusitania (1907) 760 ft long, 65,000 S.H.P. on four screws, and *Mauritania* (1907) started a new era. Their speeds of 25 knots were several knots faster than other ships. They were in every way improvements over previous ships, and their spaciousness and elegance set new standards of passenger accomodations; the deck space provided being a notable feature. Following service experience by others with turbine drive aboard several small ships, the Cunard Company appointed a Committee to recommend the type of propelling machinery for these ships. This Committee courageously recommended the fitting of four Parsons' turbines. This Reviewer notes that at about the same time

* Notes in parenthesis carrying the initials R.A.M. are those of the reviewer, Mr. Miller.

Cunard ordered the building of the medium size *Caronia* (1904) with twin screw reciprocating engines, and *Carmania* (1905) with triple screw turbines of 18,000 S.H.P. The hulls were identical, excepting for the differences required by the two types of engines. These ships provided a direct comparison of the two propulsion systems, and *Carmania* furnished over a year of fair size turbine experience before the larger ships entered service. After *Lusitania* and *Mauritania* there followed a series of very large, but somewhat slower ships: *Olympic* (1910), her ill-fated sister *Titanic* (1911), *Britannic* (1914), and *Aquitania* (1914).

The features of *Lusitania* and *Aquitania* were integrated in *Queen Mary* (1936) and *Queen Elizabeth*. They are designed for a weekly crossing schedule on the North Atlantic and to combine reliability and efficiency with amenities for passengers of a standard greatly beyond that previously attained.

Referring specially to North Atlantic liners the early ships had a length to beam ratio of about 10. A table in the Paper gives dimensions showing the Length-Beam Ratios to be: *Great Eastern* (1859) 8.28; *Servia* (1881) 9.90; *Aurania* (1882) 8.24; *Umbria* (1884) 8.77; *Teutonic* (1890) 8.82; *Campania* (1893) 9.23; *Oceanic* (1899) 10.08; *Lusitania* (1907) 8.68; *Olympic* (1910) 9.24; *Aquitania* (1914) 8.97; and *Queen Mary* (1936) 8.18. Interestingly *Queen Mary* is only slightly beamier than *Great Eastern*. Also Cunard ships are shown to be consistently beamier than White Star ships.

The Author includes a plot of the above ships relative to Prof. E. V. Lewis' method of determining whether a ship would be relatively dry or wet in storm seas. *Great Eastern, Servia, Olympic,* and *Aquitania* are on the "dry" side of the curve, the other being on the wet side. As four of the ships before 1899 are on the "wet" side of the curve, and only 2 of them are on the "dry" side, I do not understand the Author's statement: *"Servia* and other ships of the period fall within the zone in which, according to Prof. E. V. Lewis, a dry ship was to be expected, and though this circumstance was probably fortuitous, it no doubt led to a mitigation of the rather uncomfortable conditions which were experienced by passengers on the North Atlantic in those early days." Nor do I understand the statement "it will be seen that on this criterion the modern ships are more favorably placed than those built in the last two decades of the twentieth century." (Note: The Author has since stated that the phrase "twentieth century" should read "nineteenth century"). I note, however, that of the twentieth century ships listed, only *Olympic* and *Aquitania* are on the "dry" side of the curve. Clarification before the Transactions are printed is suggested.

A high ratio of length to depth persisted for many years, reaching its high point of 14.5 in *Compania* and *Lucania* (1893); increasing from 11.7 in *Great Eastern* (1859) and diminishing to 12.93 in *Queen Mary* (1936). The adding of tiers of superstructures to get more passenger space resulted in increased beam relative to length previously noted, and with the lower tier's included in the hull girder, in the reduction of the length to depth ratio. These changes have not, however, materially altered the displacement-length ratios, the highest being 112, and the lowest 76, with 93 as an average. This value is 88 for *Great Eastern* and 87 for *Queen Mary*. Also, positions relative to the Lewis curve have not altered much.

The absence of high superstructures in British passenger ships in the late 19th century was largely due to British legal restrictions. Foreign competition forced the removal of the restrictions in 1906, permitting *Lusitania* (1907) and *Mauritania* (1907) to have three tiers of superstructures.

The addition of several tiers of superstructures created problems of strength and stability. Theoretically, integrating the tiers of superstructures into the hull girder is desirable. Effective integration is, however, difficult in practice. This difficulty was realized as early as 1878, when expansion joints were advocated. Expansion joints have been troublesome, however, and, in 1915, Dr. J. Montgomerie advocated that scantlings of superstructures should be such that the hull's allowable stress would not be exceeded in any tier of houses, thus avoiding the need of expansion joints. No final solution has been found as regards steel superstructures, however, and there are still advocates for expansion joints, and for integrated superstructures. The answer may well lie in the use of aluminum superstructures, as aluminum's low Young's modulus permits greater strains without excessive stresses.

The present practice of placing large openings in the ship's sides and in deck house sides, plus the frequently irregular shape of deckhouse sides in plan view, make effective integration with the strength girder very difficult. Recent studies and tests have shown that if steel superstructures comply with the following conditions: the length is about 60 percent of the ship's length, the deckhouse sides are not too remote from the ship's sides, and are reasonably continuous both with regard to position and construction, then expansion joints may with advantage be eliminated. Contrarily, if, as is often the case, these conditions cannot be met, then expansion joints should at least be considered.

Aluminum superstructures weigh about half of the steel superstructures they replace, and broadly, permit three tiers of aluminum structures in place of two tiers of steel structures for a given beam, without detriment to stability.

Hogging stresses were calculated for eight ships, based on wave heights of $1.1\sqrt{L}$, with only small amounts of fuel remaining, and cargoes limited to 2,000 tons. (To allow for the variation in the allow-

able stress in relation to length, the factor needed to make the stress given by $\sqrt[3]{L}$ equal to the calculated stresses. has been added. R.A.M.) The ship, stresses, and factors are: *Great Eastern* (1859), 8.2, 0.933; *Umbria* (1884), 9.3, 1.171; *Campania* (1893), 8.4, 0.996; *Oceanic* (1899), 7.9, 0.896; *Lusitania* (1907), 8.0, 0.876; *Olympic* (1910), 7.4, 0.782; *Aquitania* (1914), 7.6, 0.798; *Quen Mary* (1936), 7.1, 0.820. The Author states that these figures show a decided nominal stress reduction over the period. Since *Umbria* with her high nominal stress gave satisfactory service, (probably with little to spare), modern ships have a good strength margin. In this sphere, too, passenger ship safety has increased with the years.

In addition to the reasons given for placing machinery amidships in cargo ships, there has been an important additional reason in large, fast passenger ships — the very large proportion of machinery spaces and coal bunkers to the ship's length (being 70 per cent in *Mauretania* (1907)) making the amidship position necessary. The reduced size of machinery spaces, the reduced fuel needed, and the use of oil fuel that can be readily stowed where most desirable, have made practicable the machinery aft. The aft location has its drawbacks, however, as valuable sheltered passenger open deck space is lost, and the bending moment in a 700 foot ship has been found to be 10 percent greater, thus requiring increased hull weight. (The reduced weight of shafting and shaft alley bulkheads tend to reduce the net weight increase, however. RAM). The designers of *Southern Cross* and *Canberra* evidently consider that, for the service of these ships, the advantages of machinery aft are greater than the disadvantages.

As the century under review started, paddle propelled passenger ships had reached their practical limit. Although many passengers were partial to paddle wheels, the increased efficiency of screw propulsion and the highly desirable amidship passenger space available when paddle wheels were not fitted, could not be ignored. Single screw passenger ships reached their climax in *Umbria* (1884) and *Etruria* (1884) each with a 3 cylinder compound engine, developing 14,700 I.H.P. The triple expansion engine had a long, honorable career in passenger ships. *Compania* (1893) had twin, 5 cylinder triple expansion engines, developing a total of 26-650 I.H.P. As previously noted, the sister ships (excepting for propelling machinery) *Caronia* (1904) and *Carmania* (1905) followed the spectacular results of *Turbinia* (1897). *Carmania's* successful service tended to confirm the decision to fit four direct drive turbines totalling over 65,000 S.H.P. on *Lusitania* (1907) and on *Mauritania* (1907). *Laurentic* (1909) introduced an intermediate design wherein exhaust steam from reciprocating engines drove turbines. This design reached its apex in *Olympic* (1910), where twin 4 cylinder triple expansion engines, totalling 34,000 I.H.P. exhausted to a 17,000 S.H.P. turbine driving a centerline screw. Steam turbines were used alone for later high powered ships. *Aquatania* (1914), having less speed than *Lusitania* and *Mauritania,* developed 56,000 S.H.P. with 4 direct drive turbines. There was a great advance with *Queen Mary* (1936) with a total of 160,000 S.H.P. from 4 geared turbines.

The Author's table shows that steam pressures rose from 90 psi in *Servia* (1881) to 400 psi in *Queen Mary* (1936). As power rose, the number of Scotch boilers multiplied, reaching a maximum of 24 double-ended and 5 single-ended boilers in *Olympic* (1910), all being 15 feet 9 inches in diameter, and having a working pressure of 215 psi. *Aquitania* (1914) had 21 double-ended boilers of 17'8" diameter, and a steam pressure of 195 psi, being the last, very large ship having Scotch boilers. The introduction of water-tube boilers, of which there were 24 Yarrow type in *Queen Mary,* reduced to 12 in *Queen Elizabeth,* altered the situation entirely.

In this range of passenger ships, coal used was reduced from 1.9 lb/I.H.P./hr. in *Etruria* and *Umbria* (1884) to about 1.5 lb/I.H.P./hr in coal burning liners about the beginning of the century. The use of oil fuel brought benefits that were probably greatest in passenger liners. The number of firemen was greatly reduced, and those remaining were freed from strenuous and brutalizing work. Coal passers were eliminated and less weight of fuel had to be carried. When *Olympic* (1910) was converted to burn oil, the fuel used was reduced from 1.2 lb coal/S.H.P./hr. to 56.86 lb oil/S.H.P./hr. for all purposes. In *Queen Mary* (1936) the fuel used was reduced to 0.56 lb/S.H.P./hr. for propulsion only.

The author introduces the section on "Machinery" by saying that hull design cannot be divorced from that of machinery, however much a naval architect might wish that it could be; so some attention must be given to marine propulsion development during the last century. This section is limited to indicating a few of the salient advances insofar as they concern the naval architect and the general design of ships. The two aspects of machinery which mainly concern the naval architect are the thermal and mechanical efficiency, which governs the bunker space needed, and the machinery weight and volume. A marine engineer, in addition, must provide reliability, as from the owners' viewpoint, reliability is of prime importance, but it need not concern a naval architect, who has enough troubles of his own. He might say, however, that delays and inconvenience to shipping are mainly due more to machinery failures than to hull failures.

A century ago, there were about four million net tons of British sailing ships, and about 300,000 gross tons of British steam ships. About 19 years later, the net tonnage of sailing ships equalled the gross

tonnage of steamships. Thirty-five years later, sailing ships had all but disappeared, although some large sailing ships were built in the 20th century, they being able to economically move certain types of cargo.

Oil fuel was the main force dictating the evolution of marine propulsion, first in place of coal in boilers, and then with heavy oil engines. Early oil burners were not very successful, but were improved, and oil-burning steamers were in service before 1900. Three per cent of the world's steamship tonnage used oil fuel by 1914, and by 1958 but 13 per cent used coal. Similarly, but ½ per cent of the total world tonnage was propelled by Diesel engines in 1914, whereas this figure had increased to 40 per cent in 1958.

Time lags existed between the development of improved forms of reciprocating engines and their general adoption. Although successful compound engines had been fitted to ships as early as 1856, their use did not become general until 1870. When the advantages of compound engines had become known, including the major one of less fuel being used, many ships were re-engined. Although small three crank marine engines were built in the 1870's, the triple expansion era can be considered as having started with *Aberdeen* (1881), of about 4,000 deadweight tons, having engines of 1900 I.H.P. Some 50 triple expansion engines had been fitted by 1887. The fuel used was some 30 per cent less than was used by compound engines.

The use of steel in lieu of iron had an important effect on machinery as well as on hull. Iron boilers used with compound engines, had working pressures of 60-90 psi in the 1860's. Steel boilers used with triple expansion engines had working pressures to 150 psi. (Pressures of around 200 psi were used later. R.A.M.) Although the external appearance of triple expansion engines differed but little over a half-century, great improvements were made during that period. The ultimate stage of the triple expansion engine was reached between World Wars I and II, when the reheat-system was developed. This, again, was a new application of an old idea, used in a compound engine as early as 1870.

Parsons built the first compound steam turbine coupled directly to a dynamo in 1884. *Turbinia* went on trial in 1894, with disappointing results due to inefficient propellers. With improvements in propellers and machinery, a speed of 34 knots was attained. Her spectacular performance at the 1897 Naval Review brought to public attention the great possibilities of turbine propulsion. The first trans-Atlantic ship having turbine propulsion was *Virginia* (1904). Consideration of propeller efficiency fixed shaft speed and the directly connected turbine at 180 RPM on *Lusitania* (1907) and *Mauritania* (1907), causing very large diameter low pressure rotors. *Aquatania* (1914) was the last great Atlantic liner built in Great Britain to have direct drive turbines.

An experimental single reduction geared turbine was fitted to *Vespasian* in 1909. It was successful enough to warrant more installations. Double reduction gears were fitted to *Somerset* in 1918. There were gearing troubles at that time, and there was a reversion to single reduction gearing until the trouble had been overcome. Steam turbines were principally fitted in high power passenger ships. Steam conditions varied from 220 psi saturated in Scotch boilers in *Franconia* (1923) to 600 psi and 800° F. in Yarrow boilers in *Caronia* (1948). Steam turbines were not fitted to many cargo ships before World War II, excepting in U.S.A., where Diesel engines were not favored. Since World War II, however, steam turbine installations as low as about 6,000 S.H.P. have been fitted to cargo ships and tankers.

Turbines using reciprocating engine exhaust steam to increase fuel economy were popular in the 1930's. This was, however, but a step in the evolution of the marine engine, rather than a distinct line of advance.

The steam reciprocating engine was unchallenged for the first half of the past century. In 1910, however, a 500 H.P. Diesel (reciprocating) engine was fitted to the 1,200 ton tanker *Vulcanus*, the first ocean-going merchant ship so fitted. The new era really started in 1912, when *Selandia* went in service with 2 single acting four-stroke cycle 8 cylinder Diesel engines developing a total of 2,100 S.H.P. Extensive development work followed. Low freight rates and keen competition after World War I spurred the fitting of Diesel engines in British and European ships. The four-stroke-cycle engine with airblast injection predominated in the 1920's, this type reaching its climax in the twin 10 cylinder double acting engine of 20,000 combined B.H.P., fitted in the passenger liners *Britannic* (1930) and *Georgic* (1932).

Concurrently, the two-stroke cycle engine was developed, and is now the general type. The double acting engine was favored for a while, but opposed piston engines excepted, has largely disappeared, and the single acting engine now dominates the marine field. The two-stroke cycle double acting engine reached a high state of development in the twin 10 cylinder engines of 32,000 B.H.P. fitted in *Sterling Castle* (1936) class.

The power per cylinder has gradually increased, and with turbo-charging increasing the effective mean pressure, outputs of 2,000 S.H.P. per cylinder can be attained with higher powers in view, so that 20,000 H.P. on a single screw can be contemplated. Two important developments were: the use of solid fuel injection in the early 1930's, in lieu of airblast; and the use of boiler oil as fuel. The first led to a reduction in specific fuel used, and the second altered the economics entirely.

Whilst standard forms of machinery were being improved, variants, such as medium speed geared heavy oil engines, were being developed. The gas turbine is also being developed, but the Author considers that the immediate future lies with the free piston gasifier. In general, these new engines are not as thermally efficient as the normal heavy oil engine, though other considerations may outweigh this factor at times. The following efficiencies are listed: heavy oil engines, 0.39; gas turbines (open cycle) 1250° F.), 0.29; free piston and turbine, 0.33; steam turbine (850 psi and 1950° F.), 0.32. (Note: The Author has since stated that the temperature given as 1950° should be 950°.)

The Author presents a chart showing curves of BTU's/SHP/hr on years. The difficulty of presenting accurate data from conflicting reports is discussed. Oil is assumed to have 19,000 BTU per lb and coal to have 13,000 BTU/ton-), (obviously pound is meant). The best data available shows compound engines requiring 50,000 BTU/SHP/hr in 1860, and 43,500 in 1880. Similar values for triple expansion engines are 34,500 (1880) to 20,000 (1930), to 12,500 (1940) when exhaust turbines, etc. were used to increase efficiency. Similar values for steam turbines are 21,500 (1909) to 10,200 (1960); and oil engines 10,000 (1911) to 6,200 (1960).

Broadly, in terms of lb coal/IHP/hr., early compound engines used about 3½ lb, reduced to about half (1.8 lb) in triple expansion engines by about 1890, remaining near this figure until the 1930's when about 1.0 lb was achieved. The earliest data available on a geared turbine in what may be termed a pure cargo ship is from *Kinross* (1913), having a single reduction geared turbine of 1,500 SHP using 1.6 lb coal/SHP/hr., being about 15 per cent less than reciprocating engines of the time. This figure had been reduced to 1.3 lb by 1920. With higher steam conditions the oil rate has been reduced to 0.50-0.60 lb/SHP/hr., depending on cycle and steam conditions for modern machinery of about 7,000 SHP.

Similar improvements have been made in higher powered installations. *Lusitania* (1907) used 1.5 lb coal/SHP/hr., but *Franconia* (1923), used only 0.7 lb oil/SHP/hr., for propulsion only, with Scotch boilers delivering saturated steam at 220 psi. In 1930, installations of about 18,000 SHP used about 0.70 lb oil/SHP/hr. for turbo-electric drive, and about 0.60 lb oil/SHP/hr. for geared turbine drive. *Caronia* (1948) with Yarrow boilers, working at 600 psi and 800°F, used 0.53 lb oil/SHP/hr. for propulsion only. The law of diminishing returns appears to operate, making more and more expensive the attainment of smaller and smaller decreases in fuel rates.

Fuel rates for heavy oil engines were initially low, being about 0.45 lb/SHP/hr.. in *Selandia* (1912). The rates were reduced to 10 per cent with solid injection. Present engines have a fuel rate of about 0.36 lb/SHP/hr.

As Froude tested his first model in Torquay in 1872, there has been a firm basis for powering ships during most of the past century. There are not much data, however, to show how propulsive efficiency in the widest sense, has improved over the years, partly due to the natural reluctance of ship owners and builders to publish trial and service results; an inhibition that has persisted until recent years.

We are fortunate that Messrs. Denny, published the trial results of *Merkara* in 1876. Her performance and that of other ships were analyzed by Mr. D. Moor's basis to determine the QUASI PROPULSIVE COEFFICIENT (QPC) at $0.65\sqrt{L}$. A. table gives QPC values of 0.40 for this *Merkara* (1806) (The Author has since stated that 1876 is the correct date); 0.63 for *Pacific Reliance* (1922), and 8.95 for *Lubunbashi* (1953). The British standard World War I ship had a QPC of about 0.60. No great interest was taken in cargo ship propulsive efficiency until after World War I, when experimental work showed that the effect of form and appendages was greater than had been supposed. By 1932 the effects of streamlining the stern frame and rudder gave an improvement of 20 per cent at 10 knots. The author concludes that the combined hull and machinery efficiency, on a heat unit basis, has increased, say, 12-fold during the past 100 years.

The increase in efficiency of passenger ships has not been as great, as the initial standard was higher. For ships of the same speed-length ratio and proportions, there has been an improvement of about 18 per cent in the total resistance between *City of Paris* (1888) and *Queen Elizabeth* (1940); the residual resistance being improved 43 per cent. This applies to hull form only and does not include improvements in the design of appendages and propellers.

The use of iron for ship building was fairly well established in the 1840s, but fouling restricted its use to coasting and steamships. The fouling of iron prolonged the use of wood in deep sea ships, the use of wood finding its highest expression in the fine, composite sailing ships of the 1860s. The opening of the Suez Canal ended this epoch. By 1860, seagoing wooden mail steamers had been superseded by iron steamers, culminating in *Great Eastern* (1859). In the 1860s, Lloyd's Register required the tensile strength of iron plates to be 20 tons/sq. inch, and in 1877 required also that the tensile strength across the grain be 18 tons per sq. inch. Iron was then a reliable material, and was used for many years.

The first Bessemer-steel was not satisfactory, but steel of fairly consistent quality was available by 1861, and *Cuxhaven* (1865) of 1,250 gross tons, was built of Bessemer steel. She encountered a cyclone and collided with another ship on her maiden voyage, her plates giving a good account of

themselves. The Bessemer process does not, however, permit close control, and considerable unsatisfactory steel was produced. Siemens-Martin open hearth steel was first produced in 1868. As it could be closely controlled a more consistent quality could be obtained. Lloyd's Register accepted the use of open hearth steel in 1877, allowing a scantling reduction of 20 per cent as compared to iron, resulting in a weight saving of about 13-14 per cent. This steel was required to have a tensile strength of 27-30 tons/sq. inch. Apart from the natural hesitancy of using a new material, open hearth steel cost considerably more than iron at first, thus retarding its use. As the use of this steel increased, its price was reduced. By 1890, the price of steel was about 15 per cent less than the price of iron.

As there were those who opposed the use of iron in lieu of wood, there were those who opposed the use of steel. The superiority of steel over iron was clearly shown, however, when several steel ships hit rocks. The steel was merely dented or bulged, whereas informed opinion was that iron would have split under similar circumstances, with the probable loss of the ships. Steel had almost entirely replaced iron for ships by the mid 1890s, being mostly open hearth, though some Bessemer steel was used until 1902, when Lloyd's Register banned it as a result of some extremely brittle steel being delivered. High strength steel was first used in the topside of *Lusitania* (1907) to reduce weight. Some ships were built after World War I with steel having a higher limit of proportionality than ordinary steel, but the small reduction in scantling did not compensate for the disadvantages, such as the difficulty of identifying this steel in the ship and its probable lack of availability when repairs were needed.

One disadvantage of ordinary converter steel is that the nitrogen content is 2 - 3 times that of open hearth steel, due to the use of an air blast. In the early 1950s, the use of pure oxygen replaced air, producing steel at least equal to ordinary mild steel, but much more quickly than in open hearth furnaces. This reviewer wishes to mention that the short time of the converter process may not permit the control needed to get adequate and consistent quality.

Although notch sensitive ship steel has existed for many years, this defect did not assume great importance until welded ships were built. Many failures show that steels having high toughness at low temperatures were essential for welded ships. The matter was studied intently, and the various authorities cognizant of ship construction, issued generally similar but differing specifications for ship steel. The resulting confusion was largely eliminated in 1959, when the seven principal classification societies formulated a general specification for ship steel. There are three basic grades, with 2 variations, called Grades A, B, C, D, and E. The three basic Grades are: (1) Ordinary mild steel for internal structure, and for hull girders when not over say, ¾ inch; (2) A more closely controlled type for the main hull girder flanges of greater thickness; and (3) a very high notch tough steel for use as crack stoppers. The specifications limits both chemical and physical properties. Grades A through D are to have tensile strength of 26-32 tons/sq. inch. Grade C over 1¼ inch thick, is to be normalized, as is all steel of grade E. Grade D is to withstand an impact test of 35 ft-lbs/min. at 0° C., while Grade E is to withstand an impact test of 45 ft-lbs/min. at -10° C.

Aluminum was first used in ship construction in 1895 but made little progress in the next 40 years, as no alloy suitable for marine use had been developed. Several successful alloys were developed in the 1930s, but were mainly used for light craft and life boats until after World War II, when they were used to a limited extent in cargo ship deckhouses. Aluminum alloys for ship construction have been standardized into 2 general groups—heat treatable and non-heat treatable. The tensile strength is 17 tons/sq. inch, and the 0.1 per cent proof stress is not less than 8 tons/sq. inch. The rather slow use of aluminum is said to be due to its high cost and riveting difficulties, although this reviewer is not aware of riveting difficulties. This reviewer knows of many thousands of rivets successfully driven without difficulty in aluminum ship structures. Any riveting difficulties have been overcome by the development of inert gas shielding of the welding arc, (but the welding reduces the strength of the basic metal having high strength gotten by heat-treatment or strain-hardening. R.A.M.). Much has been written about the economic advantages of aluminum, but its greatest use will probably be in the superstructures of large passenger ships, as discussed herein previouly.

The theory of longitudinal ship strength is based on the 18th century work of Bouguer, but theoretical knowledge advanced slowly until Rankine, in 1866 dealt with ship's longitudinal strength in a very impressive and modern way. He divided the bending moment into two parts, one due to the bending in still water, and one due to the passage of a wave. He gave the general rule that the maximum bending moment was WL/20. The practical approach to iron ship strength was made as early as 1841, when a Lloyd's Surveyor reported on the fracture of the sheerstrake and side of ship *Iron Duke*, which grounded at Yarmouth. He wrote that calculations assuming the side to be two thin iron beams showed that failure could be expected. What calculations he made are not known, but were probably somewhat like those suggested by Sir William Fairbairn (1860), assuming the ship being supported by a rock amidships. The Fairbairn formula is W=ADC/L, where A=Deck Area, D=Depth, C=a Constant, L=Length, and W=Load to cause

failure. This reviewer notes that A=Beam times Length, and by substituting LB for A, the Ls cancel, leaving the formula BDC, or W=the Amidship Area×C. This, obviously, could be true only when L bore a constant relationship to BD.

The approach to the strength of *Iron Duke* was the very practical adjusting of scantlings to service experience. The determining of scantlings from service experience, successful or otherwise, may lead only to gradual changes and improvements, but it is safe and sure, and cannot be replaced by a purely theoretical approach. Theory, experiments and experience can each contribute, but no one of these can be excluded.

The theoretical aspects of ship strength was greatly advanced by John's 1874 paper, which introduced the method of comparing stresses in different ships, which has remained the accepted basis of comparison.

Some years passed before theoretical calculations were compared to actual results. Calculations from the observed deflections of two ships while loading in 1894 showed Young's Modulus to be rather less than the accepted value of a steel specimen.

The strength tests on HMS *Wolf* in 1903 were extensive, stresses for hogging and sagging from known bending moments in drydock, and stresses at sea being measured. Although the gauges may not have been very accurate, and the thin plating, generally less than ¼ inch, may have permitted local behavior to influence the behavior of the girder as a whole, the work was notable in the context of the times. The next stress measurements at sea were made on the cargo ship *Ancon* in 1913.

Stress measurements at sea were continued between World Wars I and II, culminating in the observations on *San Francisco,* when a great step forward was taken in this kind of work. The test program and instrumentation were by far the most ambitious to that date. In addition to strain measurements, synchronous records were taken of the water pressure on the hull, accelerations, angles of roll and pitch, and the like, and records of slamming. Analysis showed hogging moments less than theoretical with Smith correction, but sagging moments were more.

A series of experiments were undertaken in both Great Britain and the United States to investigate the numerous failures of welded ships during World War II. Tests were made on riveted and welded tankers, and riveted and welded cargo ships, to find the response of such ships to known static bending moments, and thus enable a comparision to be made between the two systems of construction. The test showed but little difference between the efficiency of riveting and welding in this respect, but they shed much light on the basic problem of the strength of the ship's girder. The summary by Mr. Vasta (Buships) concerning full-scale structural tests is mentioned, and his main conclusions are included: i.e.; that the hull structure acts as a hollow box beam, and obeys the elementary beam theory remarkably well; that in calculating the moment of inertia of the skin all longitudinal material having continuity, is fully effective in resisting hull girder bending moments; and that measured hull girder vertical deflections agree remarkably well with theoretical calculations.

Supplementing the static bending moment experiments, the actual stresses at sea were investigated for over two years on the all welded cargo ship *Ocean Vulcan,* one of the ships on which static tests had been made. Extensive records were taken of the sea condition, and the ship's response, including the stresses. The most important results were that, for a ship of this type in a seaway, the dynamic terms in the determination of the vertical longitudinal bending moments at amidships tend to cancel each other. Thus, a reliable estimate of these bending moments for any particular wavelength and height in head or following seas, can be made by assuming the ship in static equilibrium on the wave, with the Smith Correction. This Reviewer notes that the stresses given may not be the highest stresses, as the "built-in" or "residual" stresses are not included. The "residual" stresses may be so small as to be negligible in the case of riveted ships, but appreciable "residual" stresses have been noted in welded ships.

The practice of recording wave stresses on ships at sea is becoming common. These data are valuable both in the absolute and comparitive sense and should lead to better knowledge of the design stresses which should be adopted in various classes of ships. Referring to the concept advanced by Messrs. St. Denis and Pierson (David Taylor Model Basin) of attempting to relate the static stresses to the energy spectrum of a confused sea, the Author thought that there is obviously scope for great developments in this approach to the strength problem, and in the future, no doubt, a more precise relation of scantlings to weather conditions likely to be expected will be reached than is now possible. It must be borne in mind that the determination of suitable standards for ship strength must be based on experience, both of successful and unsuccessful ships.

Stress values for typical passenger and cargo ships built in the past century are given herein previously. The Author concludes that these values show that there has been no radical alteration of strength standards during the past century, and that the practical ship builder of earlier years built ships which roughly comply with the standards that modern knowledge shows to be desirable. The theoretical investigations outlined above have had two uses. They have pointed the way to progress, but they have also confirmed to a great extent the judgment of our ancestors, who in a crude way, arrived at reasonable results.

The Author states that beyond all question, the sea is now very much safer than it was in the 19th century. Although indifferent stability of the designs popular in the 1880's was the cause of many casualties, bad conditions of the ships and their life boats, are considered contributing factors. A table shows that the loss of crew lives fell from a yearly average of 0.48 per cent in 1877-1885 to 0.03 per cent in 1953-1957. A curve shows the percentage of world ship losses, being about 1.6 per cent in 1901, and about 0.6 per cent in 1958, the curve tending to become flat in recent years. From 1926-1957 the percentage of losses were reduced by the percentage given by the cause of loss: Abandonment, foundered and missing, 24 per cent; burning, 40 per cent; collision 20 per cent; and wreck 53 per cent. Wrecking causes almost as much loss as all other losses combined.

Too much should not be read into the above figures, but clearly the largest reduction has been in the number of wrecks, probably due to better navigation aids and more reliable machinery. Loss from collision has not lessened greatly, a matter that has not escaped notice. The lesser number of ships abandoned, foundered or missing, shows that some improvement in ships' inherent ability to resist sea forces has been achieved.

Although the above sounds impressive, ships less than about 200 ft long have 8 times the loss of ships over about 400 ft long. What can be done to reduce the rate for small ships is not clear, as they are more likely to be overwhelmed by the sea, whereas large ships are more likely to be lost by structural failure. As the losses of ships over 400 ft long (those most likely lost due to structural failure) averages slightly less than two a year (excepting war years) for the past 50 years, we may reasonably conclude that the structural strength of ships has been properly equated to the forces they have to withstand; the classification societies can draw some credit from this record.

Persons, such as Plimsoll, and various bodies and organizations have contributed to increase safety at sea, as have disasters as that of *Titanic* (1912). This resulted in the 1913 International Convention on the Safety of Life at Sea, sponsored by the British Government, as were subsequent Conventions. This work has been assumed by the Maritime Safety Committee of the Intergovernmental Maritime Consultative Organization, a specialized agency of the United Nations, constituted in London in 1959.

Freeboard is an important factor effecting a ship's safety. Lloyd's Register proposed a rule as early as 1835, which was used until after 1880. The Liverpool Underwriters and the Royal Institution of Naval Architects studied the matter, and proposed to Parliament in 1870 that freeboard should be related to the beam. This would encourage the building of unduly narrow ships. The first compulsary loadlines were those required by Lloyd's Register for awning deck ships. The loadline mark was a diamond with bars at the end, with the letters "LR".

As a result of Mr. Plimsoll's agitation, the Merchant Shipping Act of 1876 was passed requiring the locations of decks being marked on the ship's sides, with the greatest draft being shown by a circle with a horizontal line through its center. This mark was placed were the owner desired, as there was no legal formula for locating it. The Author considers that Mr. Martell of Lloyd's Register is basically responsible for the formulation of freeboard rules considering ships' characteristics. His suggested freeboard table is in a paper read before the Royal Institution of Naval Architects in 1874. Mr. Rundle, Secretary of the Liverpool Underwriters Association, contended then that the amount of freeboard was quite subordinate to such matters as the strength of deck structures, height, and the security of hatchways, elevation of ventilators and openings to engine and boiler spaces, and last but not least, the safety of crew. Loss of life from ships' decks had increased with ships' size and a few inches or even a foot more of Freeboard would not materially alter the situation. Although the classification societies have rules on these matters, the relation between freeboard and closing appliances was not explicitly accepted in Freeboard Regulations until 1930. Work on freeboard tables continued, and Mr. Martell and Sir Digby Murry produced tables suitable for various types of ships in 1882 which formed the basis for the first Board of Trade tables issued in 1886. After 5 years of voluntary application, they became compulsory by the Merchant Shipping Act of 1890, this being the start of legal regulation of loadlines. (Legal loadlines were not established in USA until some 40 years later; the classification societies assigning load lines to the great majority of USA ships in the interim. R.A.M.). Efforts towards international loadlines started in 1913, and were successful in 1930. There had been a gradual reduction of freeboard from 1886-1932, amounting to about 7 inches for a 400 ft. ship, according to Figure 25(a). The Author has since stated that differences in freeboards given in Figures 25(a) and 25(b) resulted from using differing lengths of erections when preparing the two figures. The 1930 Convention permitted less freeboard on oil tankers as a result of successful service of USA coastwise tankers with less freeboard than that required for dry cargo ships. Thirty years of international experience has justified this reduction. This Reviewer notes that in conjunction with the low tanker freeboard, forecastles and elevated walkways are required, the latter to permit safe passage fore and aft in heavy weather. Less freeboard was also permitted ships carrying timber cargoes in the wells. The Author closes the section on freeboard with pardonable pride in the strong influence his country has exercised in the formula-

tion and application of freeboard tables to all but the very smallest ships.

The Royal Institution of Naval Architects early considered subdivision. Following the loss of *London* and *Amelia* in 1866, the Council considered that a two-compartment standard should be applied, and that at least an iron passenger ship should remain afloat with one compartment broached. Some passenger ships were built with at least a one-compartment subdivision, and *Servia* (1881) is said to have had a three-compartment subdivision. As a result of a House of Commons Select Committee report, a Board of Trade Bulkhead Committee report was made in 1891, based on the effects of flooding models loaded with coal. A 2-compartment standard was urged for large passenger ships. A fairly high standard of subdivision had been introduced into high-class passenger ships, though there was lack of uniformity, when the Merchant Shipping Advisory Committee recommended in 1911 that subdivision requirements be reviewed. The loss of *Titanic* in 1912 gave great impetus to this work. This Reviewer notes that *Titanic* was built to the two-compartment standard, but that the damage was greater.

The 1912-1915 Bulkhead Committee report influenced the 1913 International Convention which required that the degree of subdivision should vary with the ship's length in a regular and continuous manner, rather than a one-and two-compartment standard adopted by the Bulkhead Committee in 1891. World War I prevented international adoption of the 1914 convention, though it was applied in Great Britain for a while. The stringent 1914 convention requirements were then relaxed, and these reduced requirements formed the basis of the Second International Convention in 1929. The general principles of this convention were that subdivision should be as efficient as practical, considering the nature of the ship's service, and that the degree of subdivision should increase with the greater number of passengers and with greater length. In practice, the standard varied from unity in the 300-400 ft range to three compartments in very large passenger ships. The 1948 Convention made very little alteration to the 1929 subdivision rules. Three flooding diagrams are shown for a 596 ft passenger cargo ship. The 1914 Convention "Passenger Type" requires four holds both forward and aft of the machinery spaces, the Factor of Subdivision being 0.416. The 1948 Convention required but three holds both forward and aft of the machinery spaces, the Factor of Subdivision being 0.569. The 1914 Convention "Mixed-Type" also required three holds, both forward and aft of the machinery spaces, but the bulkheads are in slightly different locations. Although the 1948 Convention requires a Factor of Subdivision of but 0.569, a two-compartment standard has been achieved for the ship shown on the diagrams. This is also true for the "Mixed Type" according to the 1914 standard. The 1914 "Passenger Type" rules give a three compartment standard at four points, and gave a nearly three compartment standard at six points.

Stability after damage and flooding has been recognized for many years as an important factor affecting survival at sea, but the 1929 Conference was the first at which the question of stability was considered internationally, and it only required that every new passenger ship be inclined. The 1948 Convention added that the stability should generally be positive after damage and flooding; that there should be means of correcting a heavy list; to make launching of boats easier, and to provide a safer working surface for both passengers and crew. The Author could improve the section on stability by mentioning the increase in GM that has occurred. Information readily available to this Reviewer shows that at about the turn of the century, some designers were so concerned with easy rolling that ships were built that required water ballast to keep them upright. Others, however, considered that a ship should have sufficient stability without ballast. A half century ago, some considered a GM of 1 ft 6 inches to 2 ft 6 inches adequate for large passenger ships. The consensus of USA opinion 30 years ago was that the GM for large passenger ships should be around 4-6 ft under normal sea loadings, and now these values are considered suitable for medium size passenger ships, with values of around 5-7 ft for the larger ships.

As early as 1875 a British Royal Commission was appointed to study fires in coal cargoes. Although ships had always some means of extinguishing fires, the first international consideration of the matter was at the 1914 Convention on Safety of Life at Sea. This Convention required pumps able to supply two powerful jets of water simultaneously in any given part of a ship, and recognized the merits of a continuous patrol system for detecting fires. It also established 131 ft (40 meters) as the greatest distance between fire-proof bulkheads. The 1929 Convention, again confining itself to passenger ships, extended the 1914 requirements to include fire detecting systems, and smothering gas, steam or spray was to be fitted to holds and machinery spaces. The third international convention included cargo ships of over 1000 tons gross, and standardized fire protection methods in the main vertical zones.

The British Merchant Shipping Act of 1855 was the first to require life saving appliances, and based the lifeboat capacity on the ships registered tonnage. With change in ship design, this method became obsolete, permitting boat capacity for as little as 20 percent of the persons aboard, although fine ships such as *Umbria* (1884) and *Etruria* (1884) had boats for nearly 50 per cent of those aboard. A House of Commons Select Committee made regulations, effective in 1890, requiring boats for all aboard cargo ships, and in accordance with a scale

relating to the gross tonnage, for passenger and immigrant ships. The boats required were about 50 per cent more than by the old rule, and lifeboats or buoyant apparatus for all aboard were to be fitted on seagoing ships. The continued increase of ship capacity forced an extension of lifesaving requirements in 1902. Peculiarly enough, the ratio of three lives saved by boats for every one life lost at sea, which obtained in the nine years ending in 1855, remained sensibly constant in the nine years ending in 1911, though, of course, the numbers affected decreased over that period in spite of the very great traffic increase. The 1914 Convention established internationally that ships must have lifeboats and life rafts for all aboard. The 1929 Convention required in addition buoyant apparatus for 25 per cent of all persons aboard readily available in an emergency. Also, a certain number of motorboats were required. The 1948 Convention consolidated the work of the two previous conventions and included cargo ships.

In conclusion the Author states that progress of merchant ships has been along two lines during the last century: a natural increase in size, speed and efficiency; and improved amenities for crews and in the safety of life. The most spectacular technical improvements are those of marine engine efficiency and hull propulsive efficiency. Scientific principles of design and electric welding have greatly changed ships structural design, but basically not as much as might be expected from advances in other directions. This may be because the basic material, steel, has remained unchanged for two-thirds of the century.

The general development pattern over the century can be likened to a climb uphill for the first 30 years to a plateau, then 20 years ago, the advance started again, and we might conclude that it will continue at an accelerated rate.

The author praises the Royal Institution of Naval Architects for having a profound influence in encouraging technical improvements of ships and machinery, and in increasing the safety of life at sea; and, confidently, looks forward to a continuation of this essential work.

The author acknowledges the aid he has received in preparing this paper, and expressed his thanks to all concerned.

SHIP RESEARCH IN AMERICAN UNIVERSITIES

The United States Government has placed four contracts, each worth $50,000, with the Universities of California and Michigan, and with the Massachusetts and Stevens Institutes of Technology. This money is to be spent on research during the year 1961 in order to acquire for the U.S. Merchant Marine the technical knowledge necessary to design more efficient and more competitive ships. This is a new and bold approach to such important problems but we wonder if the reservoir of technical knowledge necessary for the solution of the pre-eminently practical problems is in fact available in such establishments. Ship structure is to be studied at California, and in this country, for example, it is doubtful if any university has available the necessary qualified staff to pursue, at short notice, the problems relating to ship structure in the same way as could be done by existing organizations such as Lloyd's Register of Shipping or B.S.R.A. Michigan is to study the problems of resistance and propulsion and in this country the National Physical Laboratory would be considered as the undoubted leaders in the field of merchant marine work. The other problems of seagoing and improved control and maneuverability could also be tackled on a wider basis in this country in non-university laboratories. Here, at least, it appears is one field in which we will not have to follow an American lead.

SHIPBUILDING AND SHIPPING RECORD

"VECTORS"

WHY THE SPACE RACE?

ACKNOWLEDGMENT

The following article by Dr. Eberhardt Rechten appeared in the Fourth Quarter, 1960 edition of "Vectors," published by Hughes Aircraft Company, and is reprinted therefrom.

OUR COUNTRY IS now engaged in an effort to conquer space at a tempo almost inconceivable little more than five years ago. We did not embark upon this course easily or without considerable controversy. And we are not the only country so engaged. It was the vigorous activity of the Soviet Union which prompted the scale of our own drive and which has given the exploration of space most of the elements of a race.

Superficially, one might give the present status of the contest by saying that the Russians are definitely ahead in terms of the size of their payloads, and the United States just as surely ahead in terms of the quality and quantity of information obtained from superior instrumentation. It is also fair to state that this particular race got off to a badly organized start. The two contestants did not start at the same time, and there is some question that they are going in the same direction. The scientific merit of the entire demonstration is certainly not obvious. If a year ago the question was "Who says there's a space race?," then today the query might be, "What's the use of our racing for space?" or "What are we racing for?"

One of the remarkable things about human societies is that by the time a society is sufficiently well organized to plan everything ahead with complete knowledge of all its motivations, the society is on the way out. A dynamic society moving ahead generally embarks upon new ventures almost brashly, leaving it to later historians (from Homer to Parkinson, say) to fill in the reasons.

If our present space race were the first such venture of mankind, the reasons might be difficult to find now. But this is by no means the first time such new adventures have taken place. The motives are almost always the same, though the relative importance of one motive or another may be different.

One of the strongest motives is a demonstration of a successful society. A successful society must have sufficient organization, purpose, skill, energy and assets even to start large projects and certainly to complete them. It is far more difficult to accomplish a large and well-organized program than it is to perform a collection of smaller, independent ones. The societies which built the cities of ancient Crete, the Acropolis, the city of Rome, the magnificent churches of Europe and the wonders of the Far East were certainly not weak or anarchistic.

If the elements of competition are also present, such enterprises are carried on with salesmanship and prestige in mind. We have had "World Fairs" for thousands of years. Cities of medieval Europe built towers whose numbers and heights were an

indication of a city's wealth. Later, these same cities built great cathedrals. The sales and public relations aspects of undertakings like these were tremendously important then—and are now—in acquiring a share of the world-trade market. For example, Soviet successes in space unquestionably have affected the world market in their favor. The Russians are now selling more bridges and roads, electronic equipment, automobiles and surgical supplies to the world at large than they did before *Sputnik I*, even though the launching of *Sputnik* had no more to do with these specific world-market goods than the towers of Europe had to do with local trade. To worldwide consumers it seems readily apparent that a nation that can launch the first satellite is certainly capable of building a good bridge.

One of the more suprising but most compelling reasons for programs from the building of the Acropolis to the space effort is the need for channeling the excess energy of a society in a direction which will hold the society together. When Pericles was asked why he was proposing construction of the temples on the Acropolis, one of his strongest reasons was to provide an outlet for the energies of the youth of Athens as a way of minimizing juvenile delinquency! The late Louis Ridenour maintained that such seemingly wasteful projects as crash military programs and marginal space activities were a necessity in the United States because otherwise our excess productivity would lead to a depression. For the same reason, the U.S. Department of Labor is viewing the years 1965 to 1970 with some concern, because at that time there will be an enormous influx of raw labor resulting from the post-World War II birth-rate surge. Large projects have real value as at least a partial solution.

Although it is difficult to measure the exact value of impressive memorial projects, there is little question of the economic and social benefits they produce; aqueducts, highways, harbors, electronic components, new military devices.

More than 100 years ago, Michael Faraday was demonstrating his electromagnetic equipment to a British government committee in the hope of obtaining government support. One member admitted he was fascinated, but asked Faraday, "What practical benefits can we expect?" "I can't answer that question," Faraday replied, "but I can tell you that 100 years from now you will be taxing something like this."

National-scale adventures or works have strikingly similar characteristics whether they occurred thousands of years B.C. or in our own time. Generally, such enterprises are undertaken in time of peace and are abandoned or interrupted by periods of war. Occasionally, a major task is launched which never is successfully completed. But ones which have proceeded for some time before they were abandoned as unsuccessful, or were interrupted by war, or were destroyed by a succeeding society, are still known to us. The Tower of Babel and the Sacred Circle at Stonehenge, England, are examples of the latter. Plans failing before they start are most often lost to history.

Regardless of the undertaking, there seems always to have been a running fire of criticism throughout—often long after project completion. The criticism generally proposes smaller goals of limited participation and of more immediate need. Criticism by certain groups in Athens over Pericles' construction of the Acropolis sounds surprisingly like the criticism of our own annual defense budget. Always there have been many people to maintain that, by spending only one per cent of the budget of the large program on their own particular one, the relative benefits presumably would be greater. Curiously enough, there are seldom critics who would propose alternate programs of the same scale as the large one—with the single exception of advocates of national defense whose proposals almost invariably are an order of magnitude greater.

Although these demonstrations of a successful society are strongly concentrated in the areas of engineering and technology, to be really successful they seem to need certain elements beyond those needed for strictly functional or utilitarian purposes. We find palaces with magnificent landscaping, churches with domes far higher than needed for air-conditioning. Supporting columns are sculptured, ceilings elaborately decorated, floors inlaid. And yet, it is often expensive departures from the ordinary that are the things remembered by future generations and are the real distinguishing marks of a great success. It is these elements which are destroyed first by any radically different society trying to replace the original one. It is also such features which are continuously modified and improved by a continuation of the original society. And it is the extraordinary that is often necessary to add uniqueness or identity to a project in order to excite admiration and respect of the audience. A modern example is that part of the generally practical space program trying to place a man on the moon and return him to earth—an effort whose immediate utilitarian value is certainly controversial at best.

In other words, we might answer the question, "What are we racing for?" by stating that we are racing for the same things which dynamic and successful societies have raced for from the beginning of history.

In the light of historical precedents, we might have some modern questions about the space program: we might question size of the budget . . . position of science in the space exploration program . . . value of the Mercury program . . . .

Even the total space-program budget including all the military applications—is actually relatively small compared to similar projects in the past. In comparison, former societies customarily have car-

ried out enterprises of far greater relative scope than this. Again on a comparative basis, we might predict that the space program can grow considerably if it can attract the same relative support that built the Palace of Knossos, the Colosseum, the great cathedrals and other monuments in the past.

Despite the great interest of scientists in the space program, science is not, and cannot be, the driving force for space exploration. The reasons for this are quite fundamental. Advanced science is so abstract and so little understood even by the scientist himself, that it makes very poor public relations and propaganda to people at large. Therefore, it is not reasonable to expect a ground swell of support for scientific projects just *because* they are scientific. Scientific exploration, by its very nature, is seldom successful more than 50 per cent of the time and is often successful less than 10 to 15 per cent. Consequently, any scientific proposal is immediately subjected to alternate ones whose presumed success ratio might be higher. For this reason, studies in space are often sharply criticized by scientists working in other fields because they maintain that by expending even a small fraction of the money put into the space program they could obtain far greater results.

This criticism we have seen is classical. The more general disparagement might be paraphrased by the question. "Was it worth 150 million dollars to find out that earth was not quite round?" or "Was it worth 20 million dollars to discover the Van Allen belts?" The answer is most simply: *the purpose of such programs is not scientific but rather political, economic, social and psychological.*

If we must assign costs, we should start with these last requirements of the program first. In so doing we find that the net cost of performing a scientific experiment is actually quite small. It is no more correct to bill individual scientific experiments for all of space technology—as such—than it is to bill the hydrodynamicist for the over-all cost of advancing oceanography, when he is simply searching for the optimum submarine shape. There are considerably more returns from the space effort than the merely scientific results.

It is true of science in one sense that no great discoveries are made until the technology is ready for them; and when that time comes, the discoveries are often made independently by a wide number of researchers. The underlying principles of physics presumably always have been the same; and yet, discovery of motions of the solar system had to await development of the telescope. Formulation of the laws of electromagnetism had to await development of simple electrical components first. Now, the amount of science which can be accomplished in space must await the launching of larger and larger payloads, better and better communications, guidance, control, etc. By any comparison, the expense of developing technology far overshadows the cost of novel scientific experiment.

One further feature of science precludes its being used as the driving force for the space program; the value of scientific results is very seldom known at the time of discovery and, unfortunately, there is no theorem stating that all scientific discoveries will be valuable. It is difficult to gain immediate support when the value of scientific results may not be determined until ten to a hundred years later.

It is characteristic of pursuits such as the space activity that they most represent technological achievements of considerable magnitude. Virtually by definition, therefore, the amount of effort and cost involved are largely devoted to technological advancement. The scientist who wishes to participate in such a program sometimes must do so at his own risk. To the technologist there always will be high value in reaching the moon, planets or stars even if there were too little weight allowance to permit any scientific measurements the first time. The technologist's point of view is only seldom understood by the scientist who would maintain that there is no point in having gone to your destination unless you can measure something while you are there. It would seem the scientist has the weaker argument: if you cannot get to your destination, you certainly won't make any measurements.

We must believe that the space program is inherently a good idea and that, after the difficult start, both the civilian and the military phases are proceeding in a generally worthwhile direction. Whether we are going ahead at a great enough pace is wholly another question. The answer lies in a comparison with the U.S.S.R. In this kind of a race it does not now pay, and never has paid, to be a poor second. It is not always necessary to be markedly out in front, but it helps. In many respects, the Soviet Union is presently the pace-setter, particularly in large chemical propulsion units, which directly affect the size of the launching booster. On the other hand, prediction of the future may be surprisingly bright for the U.S.

The United States has been compared unfavorably with other countries in terms of our stature in science. Contrariwise, we never have suffered when compared with any other nation in our astonishing technological ability. Inasmuch as the space race is a demonstration of technology, the U.S. has basic assets no other country, including the U.S.S.R., can claim. Whether or not these assets will be applied efficiently to the space program is again a separate question. One measure is the budget size. If the United States were to apply the same relative effort in the space program that the Soviets apply in theirs, we unquestionably would surpass them in less than ten years—even with a five-year Russian lead-time. We are not at present putting forth this

effort, although we are exerting enough so that the gap will close slowly.

One encouraging aspect of most races is that the initial pace-setter does not necessarily win the race. Instead, the successful winner is often the one who has mastered the art of being second when it is not so important—and then being first at the final pay-off. This is a real art. It involves crowding the pace-setter so that he will begin to make mistakes and to feel the pressure. As witness, U.S. technological successes in the space race seem to be pushing the Russians in a way that hurts: missed opportunities, long periods without successful launchings, evidences of incomplete engineering. Russian pictures of the back view of the moon were surprisingly poor considering the payload weight available. Engineering deficiency seems to have been in the communication link, an area in which the U.S. has done particularly well. Not long ago the Soviet publicists virtually had to "reprint" an older achievement of sending animals up to 120 miles.

In conclusion: a year ago there was some question as to whether or not we are in a space race. We now know that we *are* in a space race and that it is likely to be a fairly long one. We are not racing purely for science. We are racing to demonstrate that we are a successful and dynamic society. We are racing for the prestige necessary in a purely economic world-market situation. We are racing as one method of channeling our excess energy and productivity and for such side benefits as may result. We are racing to demonstrate that democracy is every bit as good if not far superior to communism. And, at times, we are racing out of the sheer joy and exuberance that long have been characteristic of a proud and capable people engaged in a pursuit of happiness.

SPACE "JUDO" FOR SATELLITES

Among the firsts of weather-observer Tiros II is a new and simple system that shifts its tilt in space, using the very magnetic field around the earth that caused Tiros I to drop from its predicted axis attitude. According to Radio Corporation of America's engineers, who designed and built systems for both the Television Infrared Observation Satellites, the force of the earth's magnetic field is harnessed by a controllable electric field generated around the satellite itself. The result is described as an invisible "hand" with which ground observers can shift Tiros II, give its sensors and solar power supply a more advantageous angle. Weight of the circuitry and 250 turns of wire around the "moon's" exterior total less than two pounds.

—Research/Development Magazine

Official U. S. Coast Guard Photo

At the Annual ASNE Banquet.
Admiral Robbins, Admiral James, Mr. Hill, Armiral Leggett, Admiral Furth.

E. E. NELSON

A DISCUSSION OF THE POSSIBLE ROLE OF AUTOREDUCTION IN THE PASSIVATION OF IRON

THE AUTHOR

is a graduate of the University of Cincinnati as a B.S. in Chemical Engineering. He is a registered engineer in the District of Columbia and a member of the National Association of Corrosion Engineers and the Electrochemistry Society. After serving three years in the Navy during World War II, he worked at the Naval Research Laboratory until 1956. His work there consisted of research and development on cathodic protection of ships. Projects included design of systems for reserve and active ships, current distribution studies, and design of anodes. Since 1956 he has worked as a corrosion engineer for the Mobil Oil Co., Inc. Some of his chief projects have been cathodic protection of cargo tanks and propellers.

INTRODUCTION

THE POSSIBILITY that "autoreduction" may be important in explaining some corrosion phenomena of iron was discussed briefly in a paper presented at the Boston meeting of the NACE in October 1958 [1]. The particular point of view expressed in this paper has been seriously questioned by certain authorities. It is the purpose of this paper to examine the literature in detail to present a more convincing argument. Data from the literature are given which indicate that autoreduction will occur in solutions up to a pH of 7. Theoretical considerations show that the limit may be pH of 8 or 9 and give a good explanation of why the autoreduction rate decreases with increasing pH. If autoreduction in neutral solution is accepted as a likely possibility, then it seems strongly indicated that it would have a great influence on passivation of steel by a film. Also this leads to a more consistent explanation of the action of inhibitors such as sodium nitrite and sodium chromate. The use of alkali as a treatment for corrosion reduction is also explained.

AUTOREDUCTION IN ACID SOLUTION

Autoreduction is the name given to the reduction in solution of a film of ferric oxide by iron acting as an anode. The electrons liberated by the anodic reaction move to the cathode areas where the oxide film is reduced. Pryor and Evans [2] studied this process in acid solution. Their Figure 1 shows the time for reduction in a pH range from 0 to 2.6. This shows that the reduction rate decreases rapidly with increasing pH. Over this pH range, the time for reduction increases from 2 seconds to 30 seconds. They state that at pH 3.0 autoreduction was

not observed even after 24 hours. However, they observed that portions of the film had been undermined. It should be noted that the method used to determine the end of the reduction would not be very appropriate for slow rates.

With an iron anode and impressed current (Figure 6 of [2]) the ferric oxide on an iron cathode was reduced in 3 to 4 minutes. The pH of the solution was 5 and the potential about −0.56 volts on the hydrogen scale. This potential is more positive than the calculated potential of −0.62 for the $Fe \rightleftharpoons Fe^{++}$ reaction at equilibrium. This indicates that autoreduction could occur at pH 5. Pryor and Evans state that the reduction of a ferric oxide film by a freely corroding iron anode could not be detected at pH 4 or above. This is in conflict with their own impressed current data. Their view implies that a reduction reaction might depend on the source of the energy. The more generally accepted opinion, as expressed in the vast literature on electrode reactions, is that source of energy is not important. The determining factor is the potential that results at the surface of the electrode as the result of the application of this energy.

In a different type of experiment these authors [3] studied the effect of temperature of ignition of ferric oxide powder on the rate of reduction of the oxide. The ferric oxide powder was deposited on a mercury cathode and the anode was freely corroding iron. Samples of the oxide were ignited at temperatures from approximately 200 to 1000°C. The rate of reduction was much greater at the lower ignition temperature (Figure 5, [3] and Figure 2, [4]). At least qualitatively, this indicates the possibility that the reduction rate of ferric oxide formed at atmospheric temperatures may be higher than any reported in these papers [2, 3, 4].

In other experiments, in the pH range of 0 to 2.0, the reduction rate was the same in either aerated or deaerated solutions (Figures 7 and 8, [3]). The current efficiency was lower in the aerated solution since part of the current went to reduce dissolved oxygen. This indicates that the presence of dissolved oxygen does not interfere with autoreduction at low pH.

AUTOREDUCTION IN NEUTRAL SOLUTION

A study of autoreduction at higher pH was reported by Oswin and Cohen [5]. Most of the experiments in this paper were conducted in deaerated solutions. The authors were primarily interested in a method for the quantitative determination of ferric oxide by measuring the reduction current. Dissolved oxygen would have interfered since part of the current would have been due to the reduction of oxygen. At a pH of 7.5 they report autoreduction rates of from 2 to 4 micrograms Fe per sq. cm. per hour (approximately 2-4 M.A. per sq. ft.). They also report from preliminary investigations that autoreduction occurred in aerated solution in the 5 to 7 pH range.

One point in this paper [5] is open to question. The reduction of ferric oxide is represented by:

$$Fe_2O_3 + 6H^+ + 2e \rightarrow 2Fe^{++} + 3H_2O$$

This indicates that the rate of reduction would depend on the rate of diffusion of H^+. In neutral solutions this would produce a much lower rate than these authors reported. For example, at pH 7 the limiting diffusion current for hydrogen ions as calculated by Stern's equation [6] is equivalent to approximately 1.3×10^{-3} micrograms of Fe per sq. cm. per hour. Oswin and Cohen report rates over a hundred times as great. This indicates that the reaction in neutral solution does not involve hydrogen ions directly and the above reaction is not the correct one. The equation does not necessarily apply even at low pH.

A somewhat different example of autoreduction is given by Robertson [7]. In his Figure 1, Robertson shows the corrosion rate of two sets of steel panels. One set is in aerated distilled water and the second set is in aerated distilled water saturated with ferric oxide. The corrosion rate of the second set is about double that of the first set. This increase can be explained by the autoreduction reaction; iron corroding supplies current to reduce ferric ions. The increased corrosion is about 3 mg. of Fe per sq. cm. in 12 days. This is approximately 8.8 M.A. per sq. ft. These experimental data are interesting because they show that autoreduction can occur at an appreciable rate at a pH near 7 and in the presence of dissolved oxygen. Also, since this rate was maintained for 12 days, an important amount of energy is involved. This indicates that autoreduction is not limited to a monomolecular layer of ferric oxide covering a steel electrode, but can include ferric ions in the bulk of the solution.

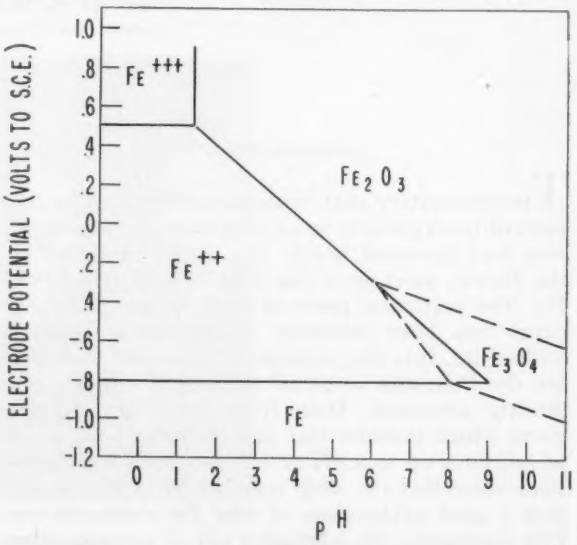

Figure 1
Stable Phases of Iron as a Function of Potential and pH (Pourbaix [8]).

THE POURBAIX DIAGRAM AND AUTOREDUCTION

References [2-5] and [7] give experimental evidence that ferric oxide can be reduced by an iron anode. A most complete theoretical discussion of the factors involved in this reaction is given by Pourbaix [8]. This author has constructed diagrams which show the stable valence states of iron as a function of potential and pH. A simplified Pourbaix diagram is shown in Figure 1. The diagram is for 3 ppm of dissolved ferrous ions. With less dissolved iron, the horizontal line between Fe^{++} and Fe is lower (more negative). The line between Fe^{++} and Fe_2O_3 would be shifted upward to the right. At higher levels of dissolved iron the lines move in the opposite directions. The lines represent equilibrium between the various valences of iron. The exact positions of the lines for real solutions are not known because the solubilities of ferrous and ferric ions are in doubt. The diagram as shown is believed to be consistent with much of the literature on corrosion.

The diagram shows that the equilibrium potential between Fe and Fe^{++} is more negative than that between Fe^{++} and Fe_2O_3 for pH below 8 or 9. Therefore, if Fe and Fe_2O_3 are in electrical contact in a conducting solution, the Fe will be oxidized and the Fe_2O_3 will be reduced. This is the autoreduction documented by [2, 3, 4, 5, and 7]. The maximum potential driving this reaction is the difference between the equilibrium potentials. The diagram shows how this potential difference decreases with increasing pH. This explains why autoreduction depends on pH and indicates that autoreduction at a slow rate should be possible up to a pH of approximately 8.

Much of this has been discussed as separate items in various papers by other authors. However, it seems to the present author that its significance has not been fully realized. Seemingly, the point of view is taken that reduction of ferric oxide is a possibility. With the present data and electrochemical knowledge, autoreduction should be considered as very nearly a certainty. The above discussion becomes more impressive when considered with the facts concerning the passivation if iron.

PASSIVATION OF IRON

If iron is made an anode using an impressed voltage, the amount of corrosion current will increase as the electrode potential becomes more positive [9]. However, above a certain potential the corrosion current drops to a very small value as the electrode potential is increased. This can be simply explained. The initial increase of corrosion rate with increased electrode potential is the normal polarization of an anode. The potential of the anode during this time is below the oxidation-reduction potential of Fe_2O_3. The reduction process of Fe_2O_3 is faster than the oxidation so no stable film can form. This is a region of general uniform corrosion. However, when the potential of the iron becomes more positive than the equilibrium potential of ferric oxide, a protective film can start forming. This reduces the exposed area of iron and the total amount of corrosion. At some sufficiently positive potential the rate of formation of the ferric oxide film is so rapid that almost no corrosion occurs. Between this potential and the equilibrium potential for ferric oxide, any bare steel will corrode at a rapid rate. This is the region of pitting corrosion.

The action of oxidizing inhibitors such as sodium nitrite and sodium chromate on iron may have a very similar explanation. These inhibitors are reduced by the iron anode. If the inhibitors are in sufficient concentration, the initial corrosion rate of iron will be great enough to polarize the iron up to the oxidation-reduction potential of Fe_2O_3. The oxide film now forms and reduces the exposed area of iron. This increases the current density on the remaining bare iron and also raises the anode potential. This continues until the iron is completely coated and corrosion drops to virtually zero. If any breaks occur in the film, the iron initially corrodes at a high rate and becomes polarized to a relative high value. This permits the break to be rapidly sealed with an oxide film. The above explains why inhibitor is used up during the initial period before passivity occurs [7] and why it is necessary to maintain a reserve of inhibitor even after passivity has been produced. Also, if the concentration of inhibitor is not sufficient, complete protection may not result. Then any breaks in the oxide film may not be healed quickly. The corrosion rate at these breaks will be high and pitting will be more prevalent than in the complete absence of inhibitor.

A study of Figure 1 shows that increasing the pH decreases the driving potential for the reduction of any oxide film. The iron anode has to be polarized less in order for the film to form and to be maintained. There must also be some source of oxygen for an oxide film to form. Thus, sodium hydroxide alone in solution is not a good inhibitor. However, with a plentiful supply of dissolved oxygen, sodium hydroxide becomes an inhibitor for iron. Sodium nitrite and chromate both can supply oxygen to form ferric oxide and can function in the absence of dissolved oxygen. Increasing the pH aids both of these inhibitors to prevent rust.

Sodium chromate has one additional desirable characteristic. Its reduction product is chromic hydroxide which Kolthoff and Shams El Din [10] have shown to be the protective film on chromium. Apparently when sodium chromate is reduced by iron, insoluble chromic hydroxide forms on the iron surface. The chromic hydroxide, unlike ferric oxide, can not be reduced by iron anodes.

The above discussion has been based on the assumption that the protective film on passivated ion is ferric oxide. While many authors have considered this the most likely possibility, it still has not been proven. A second possibility is that the film is

chemisorbed oxygen. Uhlig [11] has recently calculated the reversible potential for this type of film. It seems likely that bare steel as an anode could also reduce this film. Most of the explanation of autoreduction of ferric oxide could probably apply to a chemisorbed oxygen film.

SUMMARY

1. Literature has been cited and discussed which indicates that iron, acting as an anode, can normally cause the reduction of a film of ferric oxide in acid and neutral solutions.

2. If the iron anode is polarized, its potential may become more positive than the oxidation-reduction potential of the ferric oxide film. Under these conditions the film will be stable and a protective film will result.

3. If the solution is made more alkaline, the oxidation-reduction potential of ferric oxide becomes more negative and the driving potential between the iron and the ferric oxide is reduced. This decreases the amount that the iron anode must be polarized in order that a stable oxide film can form.

4. The oxidizing inhibitors such as sodium nitrite and sodium chromate in sufficient concentration permit a high initial flow of current from the iron. This polarizes the iron above the oxidation-reduction potential of the ferric oxide and a stable film can form.

5. Sodium chromate has one other function. The reduction product of sodium chromate is insoluble chromic hydroxide which has been shown to form a protective film on chromium. It is assumed that a similar chromic hydroxide film will form on iron and be protective.

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RESEARCH REACTOR READY FOR OPERATION IN JAPAN

The JRR-2, the largest nuclear research reactor in the Far East, at Tokai-mura, some 70 miles from Tokyo, Japan, has been officially turned over to the Japan Atomic Energy Research Institute by American Machine and Foundry Company.

Designed and built by AMF for the Institute, Mitsubishi Atomic Power Industries was an important subcontractor for the $1.5-million reactor.

The JRR-2 reactor is an all-aluminum 10-mw heavy-water-moderated tank-type reactor. Light water and steel serve as a thermal shield instead of the customary graphite and lead, in order to reduce the possibility of radiation damage in the reactor.

The Japan Atomic Energy Research Institute employs nearly 1200 people at its headquarters in Tokyo and at Tokai-mura. Established in 1957, the Institute now has 40 buildings in which a wide range of research, testing, and experimentation is conducted in the nuclear field.

—MECHANICAL ENGINEERING

GEORGE LEPPERT

BOILING HEAT TRANSFER

THE AUTHOR

served in the United States Navy from 1943 to 1946 and is a qualified submarine officer. He received the B.S. degree from the University of Wisconsin (1947) and M.S. (1954) and Ph.D. (1954) degrees in Mechanical Engineering from Illinois Institute of Technology. Engaged in heat transfer research and development at Argonne National Laboratory from 1950 to 1953, he has been on the faculty of Stanford University since 1954.

WHEN HEAT is transferred to a liquid which is at or near its saturation temperature, there may be a phase change of some of the liquid into the vapor state. The applications of such boiling heat transfer are many, not only in apparatus whose primary purpose is to vaporize a liquid, such as steam boilers, but also in situations where it is desired to remove heat from a surface at a high rate with the lowest possible surface temperature.

Historically, the engineer's primary interest in the transfer of heat to a boiling liquid has been toward the generation of steam for power production, either electrical, propulsive, or both. To this need was added, at a fairly early date, that of the manufacturing chemist, whose production processes required the vaporization of numerous liquids in distillation and other routine operations.

NUCLEAR POWER APPLICATIONS

Starting around 1948, extensive research and development directed toward nuclear power generation for ship propulsion got under way. Since the first plant was to be a pressurized water reactor for the submarine *Nautilus*, it was imperative that design criteria in water heat transfer technology be firmly established. To the student of boiling technology, it is interesting to observe the impetus given to research in this field by the development of the pressurized water reactor, which was itself carefully designed to avoid boiling of the coolant. Since that period, of course, reactors have been built in which steam generation takes place in the core, in direct contact with the nuclear fuel elements, and these have proved eminently successful.

A schematic diagram of a pressurized water reactor is shown in Figure 1. Ordinary water, highly purified and deaerated, enters the bottom of the reactor pressure vessel and flows upward through the fuel assemblies, as can be seen in Figure 2. The temperature of this water, termed the primary coolant, increases from 508 to 524°F, but since its pressure is maintained at 2000 psia, where the saturation temperature is 636°F, no vaporization takes place. The heated water then flows to the tube side of a heat exchanger, the boiler, in which water at 600 psia (486°F) is vaporized on the shell side. The primary coolant then is returned to the core by loop pumps to complete the circuit.

Before the feasibility of the boiling reactor principle was investigated experimentally by Argonne National Laboratory's Borax tests [1] and later demonstrated conclusively [2] by the success of their Experimental Boiling Water Reactor (EBWR),

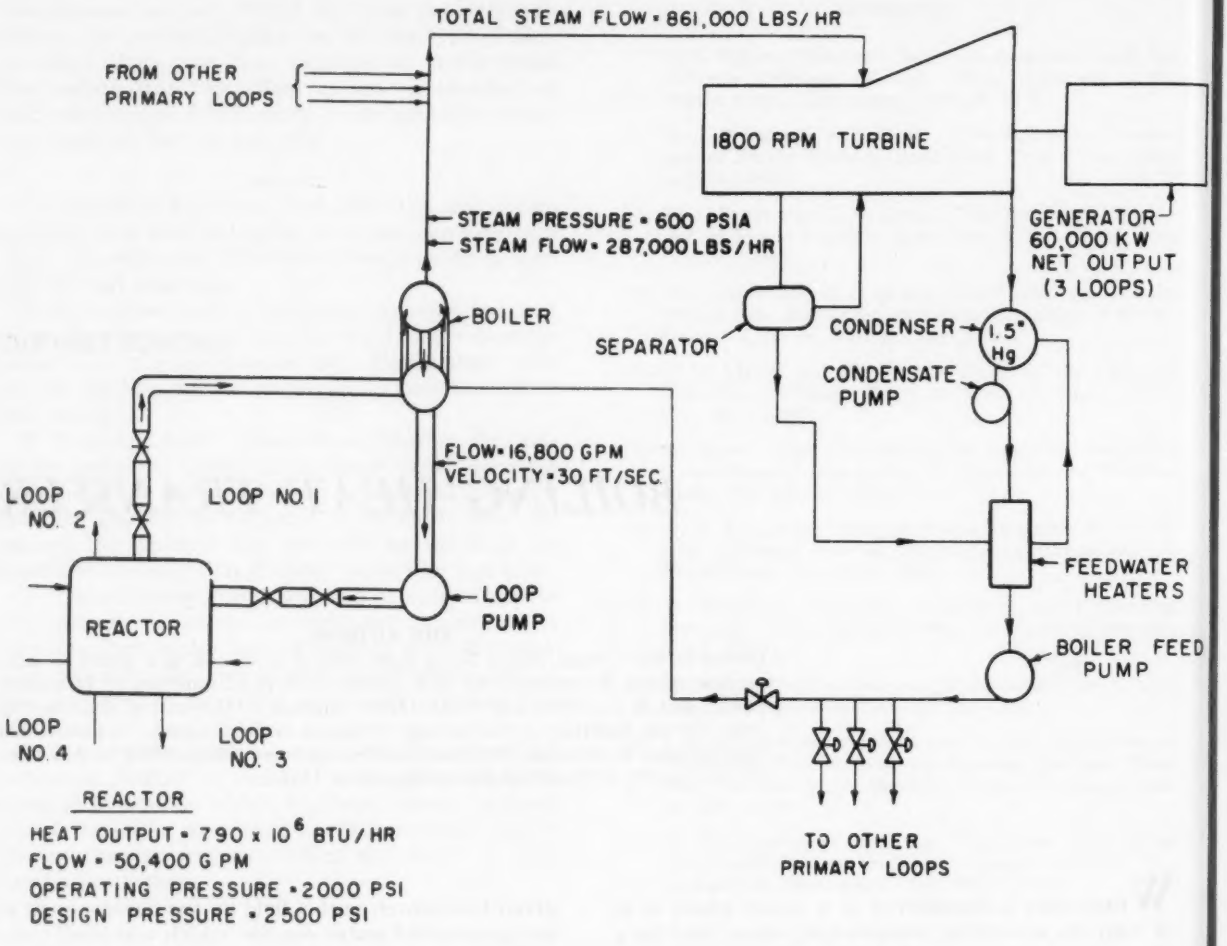

Figure 1. Plant Schematic Diagram of Pressurized Water Reactor [9].

it was thought that the variations in moderator density caused by vaporization in the core might cause power transients which would threaten the operational stability of the plant [3]. Consequently, the early boiling water research for pressurized water reactors was intended to delineate the permissible range of heat flux and the minimum velocity and subcooling required to insure the presence of the primary coolant in the liquid phase only.

The simplification which the direct boiling system affords is illustrated schematically in Figure 3. The water-to-water heat exchanger has been eliminated, as have the primary coolant pumps and the pressurizing system. Turbine steam is now generated directly in the reactor core, and, because of the low density of the steam-water mixture in the core compared to the liquid density in the downcomer, the fuel elements may be adequately cooled by natural circulation. Figure 4 shows a typical plate-type fuel element for a boiling reactor. A feed pump is still required, of course, to return the liquid water from the condenser hot-well to the high pressure circuit. Steam pressures of 600 to 1,000 psia have been found most economical in boiling reactor designs to date.

From the standpoint of heat transfer to the boiling liquid, it is almost incidental that the energy source in these reactors comes from nuclear fission. Similar plates, tubes or rods resistively heated by an electrical current would produce much the same heat transfer situation. Quite a different method of steam formation occurs in a homogeneous reactor, however, in which the fissionable material is chemically combined in a salt, such as uranyl sulfate, and carried in aqueous solution. If such a device were permitted to boil, steam formation would take place throughout the fluid volume rather than at a heating surface, as with heterogeneous reactors. Similar vapor formation takes place when a liquid at or slightly above saturation temperature is

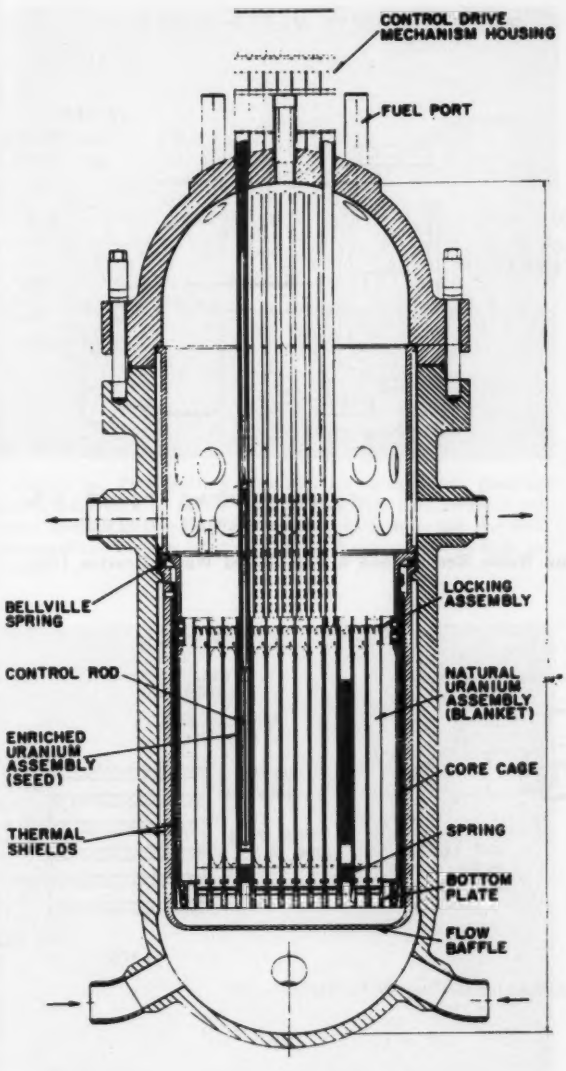

Figure 2. Longitudinal Section of the Reactor Vessel for Pressurized Water Reactor [9].

heated internally by infra-red radiation from an outside source, such as a heating lamp.

SATURATED BOILING

In many ways, it is advantageous to regard boiling as a special case of convection, either free or forced. To appreciate this similarity, consider a simple heat transfer situation, that of an electrically heated, cylindrical metal tube immersed in a few inches of water. Passage of current through the tube produces thermal energy which raises its temperature, and convective heating of the water takes place. If quantitative measurements are made when the water just reaches saturation temperature and when the heat input is small, it might be expected that vapor bubbles would form at the heated surface and that these bubbles would rise to the water surface and escape. That this is not the case has been shown by careful measurements [4], and, in fact, what happens is that the liquid near the heater reaches a temperature slightly in excess of saturation. This superheated liquid is less dense than the lower-temperature saturated liquid, and it therefore tends to rise to the free surface, where vaporization takes place. In spite of the fact that there is vaporization at the water-air interface, this mechanism is simply natural convection insofar as conditions at the heater are concerned. The temperature driving force at the heater required to produce a certain heat flux (q″) is predictable from natural convection correlations.

As the heat flux is increased, the water superheat increases to an amount which permits the formation of vapor bubbles on the heater surface. It will be observed that there are preferred locations where bubbles form, and the bubbles form in columns at these places, which are known as *nucleation centers*. For low heat flux, relatively few such centers will be observed, but an increase in heat transfer is accommodated by an increase in the number of bubble columns. Since the vapor bubbles so formed detach from the heater and rise in the superheated liquid, and since the vapor is not itself superheated, there is heat transfer to the bubbles from the liquid as they rise to the surface. Experiments [4] have shown that, contrary to intuition, most of the vapor formation in this type of nucleate boiling takes place after the bubble leaves the heating surface. Consequently, most of the heat transferred from the surface during nucleate boiling goes to the superheated liquid adjacent to the heater and not directly to the vapor bubbles which grow on the surface. Figure 5a shows nucleate boiling from a ⅛-inch diameter tube at low heat flux with relatively few nucleation centers.

Figure 6 shows the variation of heat flux with the temperature driving force, which may be taken for present purposes as the heater surface temperature minus bulk liquid temperature, for an electrically heated platinum wire [5, 6]. A similar variation has been measured with the apparatus shown in Figure 5.

At very low heat flux, the curve is a straight line on a log-log plot, which indicates a functional relation of the type

$$q'' = h(t_s - t_b)$$

where the coefficient, h, is simply the convective conductance, and is proportional to the one-fourth power of the temperature difference for natural convection in the laminar range. Consequently, the heat flux is proportional to the 5/4 power of the temperature difference [4] in the region A-B.

At heat input sufficient to produce bubble formation the surface, which is the nucleate boiling

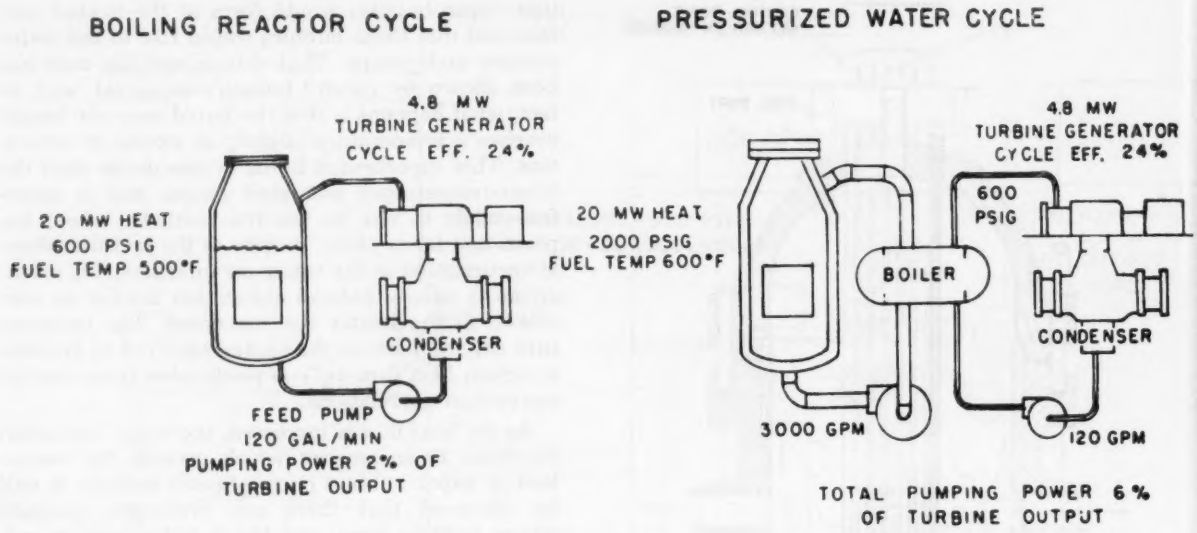

Figure 3. Schematic Comparison of Flow Cycles of a Boiling Water Reactor and a Pressurized Water Reactor [10].

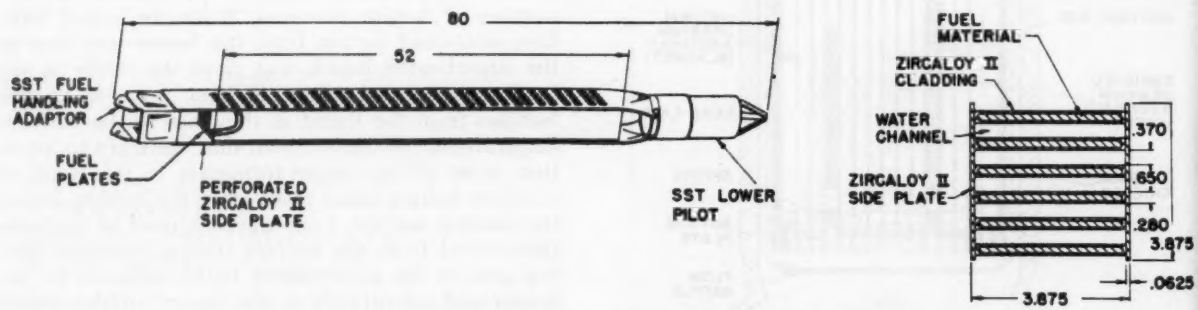

Figure 4. Fuel Assembly from the Exp erimental Boiling Water Reactor [10].

regime B-C shown in Figure 6, the rate of increase of q″ with temperature difference is much greater than before, and, as can be deduced from the graph, very large heat transfer rates are possible with a relatively small temperature driving force. This is of great practical advantage in many situations where a cooling problem exists but where the maximum surface temperature is limited by metallurgical or other considerations.

As the heat flux is increased in the nucleate boiling regime, more nucleation centers are activated, and there is more and more vapor in the vicinity of the heated surface. At some critical point (C, Figure 6), the nucleate boiling mechanism can accommodate no additional heat transfer. At this point, a vapor blanket forms over the entire surface, and the heat transfer mechanism changes completely. Figure 5b shows nucleate boiling at a flux slightly less than that which produces vapor blanketing.

Beyond the peak heat flux just described, the film boiling regime is encountered, as is indicated in Figure 6. The very large heat transfer rate must be accomplished through a vapor film, which requires a much larger temperature difference than existed at almost the same heat flux in nucleate boiling. With water, the required surface temperature is greater than the melting points of the common metals and alloys. Consequently, the phenomenon of a sudden transition from nucleate to film boiling at nearly constant heat flux is frequently called *burnout*. Figure 5c shows the failure of a stainless steel heating tube when the peak heat flux is reached.

For certain fluid-surface combinations, it is possible to operate in the film boiling regime without damage to the surface. In such cases, the entire curve in the film boiling region may be obtained experimentally. It can be seen from Figure 6 that

Figure 5a. Pool boiling of water at atmospheric pressure and a heat flux of 15,000 Btu/(hr)(sq ft). The bubbles collapse soon after leaving the heating tube because the bulk temperature is only 208° F. Three temperature probes are visible.

Figure 5b. Vigorous nucleate boiling at a heat flux of 171,000 Btu/(hr)(sq ft) and a bulk temperature of 210° F.

Figure 5c. Transition to film boiling with melting of heating tube [11].

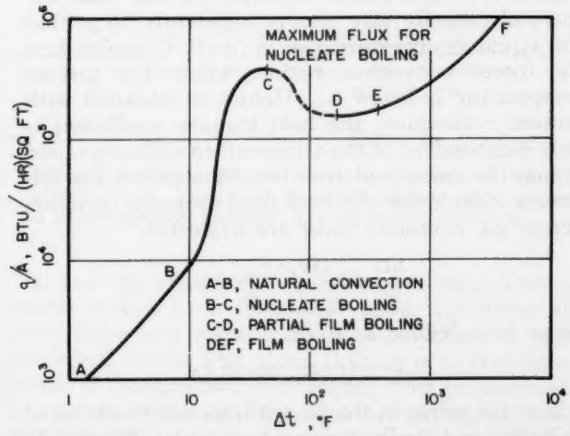

Figure 6. Boiling of water at 212° F on an electrically heated platinum wire. Data of Nukiyama, as presented by McAdams [6].

with water, for example, the temperatures are such that radiation from the surface to the liquid, through the film, will play an important part in the film boiling heat transfer mechanism.

There is a fairly wide interval in temperature between the nucleate boiling peak and the minimum stable condition at which film boiling can be sustained. This region is usually termed *unstable film boiling* and is characterized by the alternate growth and collapse of a vapor film. It can be deduced from the graph that this type of boiling will not occur in a device which has relatively constant heat input, because an increase through nucleate boiling to the peak heat flux will cause a sudden "jump" (along a horizontal line on the graph) to a corresponding point which is well into the film boiling regime. Similarly, during operation in stable film boiling, a decrease in heat flux below the relative minimum in the curve produces a jump to a point in the nucleate boiling region which is well below the peak heat flux.

With a different kind of heating, however, operation in the unstable film boiling regime becomes quite feasible. If, instead of heating the tube shown in Figure 5, electrically, it is heated internally by the flow of a hot fluid, then any desired value of surface temperature can be maintained. If the thermal capacity of the heating medium is large enough, its temperature change will be small as it passes through the tube, and the entire outer surface of the

tube can be held at practically the same temperature.

SUBCOOLED BOILING

Before examining the mechanism of nucleate boiling in greater detail, a distinction needs to be made according to whether the main body of liquid in the vicinity of the heater is at or slightly above saturation temperature, as described above, or at a lower temperature. In the latter case, which is called *subcooled boiling* or, sometimes, *local boiling*, vapor bubbles form at a surface because it is substantially above saturation temperature, but the bubbles either collapse without leaving the surface by transfer of heat to the adjacent subcooled liquid, or else they leave the surface and then immediately collapse. In either case, the heat transfer is materially improved over convection without phase change because of the violent agitation of the liquid in the boundary layer by the growing and collapsing bubbles.

Suppose liquid at constant pressure and at temperature t_o is pumped upward past the heater in Figure 5 at a constant velocity, V_I, and that the thermal capacity rate, mc, is sufficiently large that the liquid temperature rise is small. Consider first the forced convection region, where the surface temperature is below t_{sat}. Unlike its situation with natural convection, the heat transfer coefficient is now independent of the temperature difference, and it may be calculated from an equation of the following form if the effects of fluid property variation across the boundary layer are neglected.

$$\frac{hD}{k} = C \frac{DV\rho^a}{\mu} \frac{c_p \mu^b}{k}$$

Since h is defined as $q''/\Delta t$,

$$q'' = (CkN_{Re}{}^a N_{Pr}{}^b)\,\Delta t$$

where the terms in the parentheses are functions of velocity and bulk temperature only. Figure 7a shows this relationship as a log-log plot of unit slope.

Now consider what happens when the heat flux is increased until the surface temperature exceeds the saturation temperature of the liquid. As with pool boiling, bubble formation requires a finite positive surface temperature excess, Δt_{sat}. When nucleate boiling first starts, most of the heat is still being transferred by forced convection. However, as the heat flux is increased still further, the nucleate boiling mechanism begins to predominate, and the effect of convection becomes unimportant. Figure 7a shows curves for nucleate boiling at a given velocity with different bulk liquid temperatures and, therefore, different subcoolings.

It has been shown in many experiments that, over most of the nucleate boiling range, the surface temperature excess above saturation is a function of heat flux only, regardless of the subcooling. The nucleate boiling curves in Figure 7a may be represented quite satisfactorily, therefore, by a single line from which the subcooling, and therefore the bulk temperature, has been eliminated, by plotting q'' vs. Δt_{sat} instead of Δt.

Figure 7b shows the curves of Figure 7a replotted in this manner, from which it can be seen that the new curve has the same coordinates as the zero subcooling curve in Figure 7a. Since values of bulk temperature below saturation cannot be represented on the logarithmic scale of Δt_{sat}, the forced convection portions of these curves have little meaning and have been included mainly for the sake of completeness. However, they are useful for predicting where boiling starts at various subcoolings with the velocity chosen.

The effect of liquid velocity will next be examined. Figure 7c shows the idealized curve of Figure 7a for one value of subcooling, to which has been added two additional curves at higher velocities. These curves illustrate the relative independence of nucleate boiling on velocity except near the region of initiation of nucleate boiling.

Two additional remarks need to be made about the curves in Figure 7. In the first place, the transition from forced convection to nucleate boiling does not occur with discontinuous slope, as the straight-line portions of Figure 7 would suggest, but smoothly, through a transition region where both effects are important. Secondly, velocity and subcooling have a significant effect on the peak heat flux, but this portion of the curve is not shown in the figures.

THE MECHANISM OF NUCLEATE BOILING

It was pointed out earlier that in the regime of most practical importance, nucleate boiling, the heat transfer from a surface takes place chiefly by a convective process to the liquid. The high transfer rates can be achieved with fairly small temperature differences because of the very high turbulence level produced in the liquid by the vapor bubbles growing and leaving the surface.

However, the greater complexity of nucleate boiling compared with convection without change of phase may be appreciated by a consideration of the pertinent factors affecting the two mechanisms. Whereas the viscosity, density, thermal conductivity and specific heat of the fluid can be used to describe single phase heat transfer, in nucleate boiling many additional properties are relevant. The surface tension, latent heat of vaporization, saturation temperature, liquid and vapor densities and other properties of both phases must be introduced. As with ordinary convection, the configuration of the flow channel and the flow rate must also be considered, but the type of metal, the surface roughness and the presence of adsorbed gas have all been found to affect boiling heat transfer.

A lucid description of the mechanism of nucleate boiling from a submerged heater in a liquid pool was given by the late Max Jakob [4]. Professor

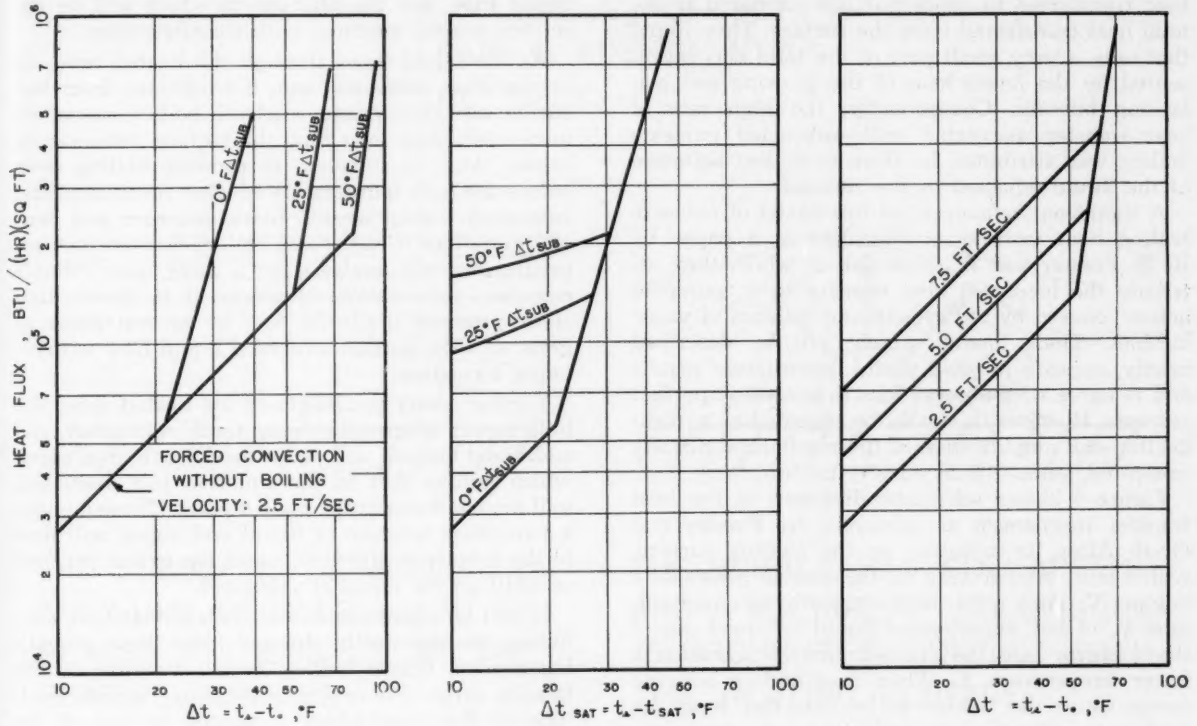

Figure 7a Figure 7b Figure 7c

Figure 7a. Variation of heat flux during forced convection and subcooled boiling at different liquid subcoolings and at atmospheric pressure. Figure 7b. Variation of heat flux with Δt_{sat} instead of Δt. Figure 7c. Variation of heat flux during forced convection and subcooled boiling at different velocities and at atmospheric pressure. The subcooling is 25° F.

Jakob, who, together with co-workers in Germany and, later, in the United States, made many important contributions to the understanding of boiling heat transfer, has this to say about saturated boiling:

Summarizing our knowledge of the mechanism of nucleate boiling on a clean, smooth or rough, heating surface, it can be said that only a very small part of the heat produced in a heater is directly transferred to the interior of bubbles adhering on the surface. The main part of the energy makes a detour through the liquid. The prerequisite of boiling is formation of a thin, considerably superheated layer of liquid on the heating surface and slight superheating of the bulk of the liquid. Vapor bubbles originate on roughnesses or from gas bubbles which exist at the heating surface. The bubble develops first by evaporation because of the considerable temperature excess of the liquid layer mentioned over the saturation temperature. The bubble breaks off when its volume has grown so much that the buoyancy exceeds the capillary forces which bind it to the heating surface. In the ensuing rise of the bubble through the bulk of the liquid, the excess of liquid temperature and the coefficient of heat transfer on the bubble surface are smaller. However, this surface and the time available for heat transfer are so much greater that the vapor formation is largest during the free rise of the bubble. Vapor bubbles subsequently originating on the same spot form a sort of swaying column; with increasing heating energy and temperature excess spots of smaller roughness satisfy the capillary conditions of bubble formation and start as new sources of vapor columns.

It is to be expected that nucleate boiling from a heater cooled by a subcooled liquid will differ in some important respects from the mechanism just described. In the first place, if there is to be a condition of steady state, some means must be provided to introduce subcooled liquid at an unchanging temperature and to remove heated fluid. Consequently, interest in subcooled boiling is usually confined to forced convection.

In the second place, the vapor bubbles which grow and leave the surface in subcooled boiling immediately find themselves surrounded by liquid colder than themselves. Instead of growing during a buoyant rise through the liquid to a free surface, the bubbles immediately collapse in the stream of subcooled liquid. Whether the vapor bubbles actually become detached from the heater before collapsing, or do so while still attached to the heater, depends upon such conditions as fluid velocity and subcooling.

In spite of these rather significant differences, the mechanism of nucleate boiling in the vicinity of the heated surface appears to be relatively independent of the bulk fluid temperature. Rohsenow and Clark [7] have studied high speed motion pictures of subcooled nucleate boiling in order to estimate the net

heat transferred to vapor bubbles compared to the total heat transferred from the surface. They found that only a very small part of the total was represented by the latent heat of the growing and collapsing bubbles. Consequently, the high rate of heat transfer associated with subcooled nucleate boiling was attributed by them to violent agitation of the liquid adjacent to the surface.

A significant refinement of this model of nucleate boiling heat transfer is described in a paper by K. E. Forster and R. Greif [8], in which they attribute the increased heat transfer to a "pumping action" caused by the growth and collapse of vapor bubbles. Their model, which will be described briefly, appears to yield useful quantitative results and to agree with observations in several important respects. However, it should be regarded as a modification and amplification of the mechanism already presented, since it is in no way contradictory.

Figure 8 shows schematic diagrams of the heat transfer mechanism as conceived by Forster and Greif. After its initiation on the heating surface, which is at temperature t_s, the bubble grows to a volume V_b. As a result of this growth, an equal volume V_b of hot, superheated liquid is forced out of the sublayer into the main stream, which is at a lower temperature, t_o. When drag and/or buoyant forces cause the bubble to be detached from the wall or to collapse at the wall, its place next to the wall is taken by cold liquid. If the temperature t_o is below saturation, the bubble collapses, and if t_o is above saturation, it grows in the main stream, but in either case its place next to the wall is taken by liquid at temperature near t_o. This model appears to explain the high heat transfer rates which are obtained with nucleate boiling, and it may go a long way toward explaining quantitatively the nearly complete independence of heat transfer rate on main stream velocity and subcooling over a wide range of the boiling regime.

FLUID FLOW WITH BOILING

In most design problems where boiling occurs, the determination of the heat transfer coefficient or, what is equivalent, the variation of surface temperature with heat flux, is only part of the information required. Data which may be of even greater importance are the peak heat flux; the static pressure drop in the flow channel; the stability of nucleate boiling and of the flow; and the density of the liquid-vapor mixture. The mixture density is especially important in natural circulation systems, where it controls the flow rate, and in nuclear reactors, where the reactivity may be a sensitive function of the moderator density.

Several different regimes of boiling flow are of interest and can be delineated. Most common, perhaps, is the situation in which either subcooled or saturated liquid is brought under pressure to the entrance of a heated channel. For convenience of discussion, it will be supposed that the channel is a round tube, but the phenomena which will be described are not confined to this configuration.

As the liquid flows through the heated tube, its temperature increases, and, if conditions described earlier are appropriate, nucleate boiling starts. At moderately high heat flux, the surface temperature excess, Δt_{sat}, is sufficient to produce boiling even before the bulk temperature reaches saturation, and subcooled boiling occurs. Static pressure and density variations in subcooled boiling flow are not yet predictable from analysis, nor is there much reliable empirical information. However, it is known that static pressure gradients may be several times as great as with similar subcooled liquid flow without vapor formation.

Further along the length of the heated tube, the bulk liquid temperature may reach saturation, and additional heating will cause the formation of vapor which, unlike that in the situation just discussed, will not condense in the main stream. Consequently, a two-phase mixture of liquid and vapor will flow in the tube from this point until the exit is reached or until all the liquid is vaporized.

It will be appreciated immediately that flow conditions are drastically changed from those prevailing earlier, before boiling began. Because of the usually large (sometimes enormous) specific volume of the vapor phase compared to that of the liquid, flow continuity requires acceleration of the fluid mixture. The magnitude of this acceleration may be quite small with subcooled boiling, especially in channels of at least moderate size, but large increases of momentum must be expected with saturated boiling.

Frictional forces between the fluid and the walls of the channel are naturally quite dependent on the velocity of the flowing mixture. The force which is required to accelerate the fluid and to overcome this increased wall friction is supplied at the expense of static pressure. For a flow channel which is not horizontal, a further change in static pressure occurs because of the change in elevation. In order to predict the magnitude of this effect, the density of the two-phase mixture must be known.

A different application of boiling flow from that in a heated channel is adiabatic flow of a saturated mixture. If liquid at saturation temperature is flowing in an insulated channel, its static pressure tends to decrease because of frictional effects. If heat losses are small, the temperature at first remains constant and the liquid becomes superheated because of the pressure decrease. With sufficient superheating, vapor begins to form. As in the case of boiling flow in a heated channel, acceleration and increased frictional effects must be made up by the continuing decrease of static pressure along the channel. Sometimes called *flashing flow*, this phenomenon is of practical interest in many engineering applications.

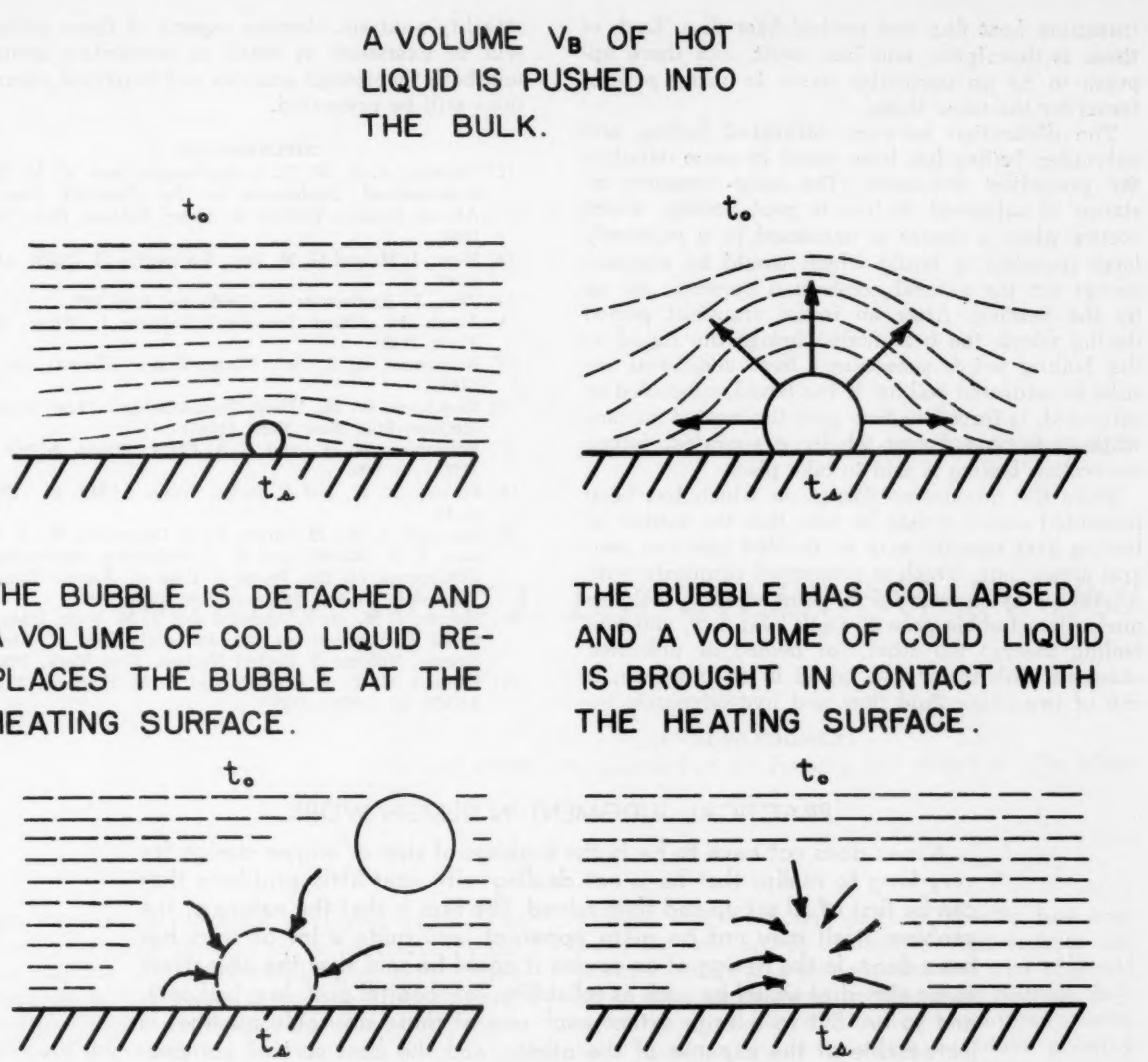
A VOLUME V_B OF HOT LIQUID IS PUSHED INTO THE BULK.
t_o
t_s
t_o
t_s
THE BUBBLE IS DETACHED AND A VOLUME OF COLD LIQUID REPLACES THE BUBBLE AT THE HEATING SURFACE.
THE BUBBLE HAS COLLAPSED AND A VOLUME OF COLD LIQUID IS BROUGHT IN CONTACT WITH THE HEATING SURFACE.
t_o
t_s
t_o
t_s

Figure 8. Schematic diagram of nucleate boiling model of Forster and Greif [8]. Lower left, vapor bubble leaves surface; lower right, bubble collapses without leaving surface.

BOILING TERMINOLOGY

There is not yet complete agreement among workers in the field on terminology for various types of boiling heat transfer, but suitably descriptive terms have been used by various authors, and a consistent terminology is evolving. One basic distinction is between *surface boiling* and *volume boiling*, i.e., whether vapor bubbles form originally at a heated surface of macroscopic size or whether they form spontaneously in the liquid. Volume boiling, which is relatively uncommon, occurs in pure liquids heated by radiation, and in solution-type nuclear reactors in which heat generation occurs in the bulk of the fluid.

There is no difficulty in distinguishing between *nucleate boiling* and *film boiling*. As was pointed out earlier, the mechanisms of heat transfer are completely different in these two regimes, with the most obvious difference being that with nucleate boiling from a surface, most of the heat transfer is to the highly agitated liquid. When film boiling takes place, on the other hand, the heater is blanketed with a layer of superheated vapor. Much less is known about *unstable film boiling*, but its practical importance is limited by its difficulty of achievement except by so-called constant temperature heaters.

When the heat transfer rate is increased to the *peak heat flux*, nucleate boiling can no longer exist, and the surface becomes covered with an insulating film of vapor. Various other terms have been applied to this heat transfer rate, including *burnout*,

transition heat flux and *critical heat flux*. Each of these is descriptive and has merit, and there appears to be no particular harm in using several terms for the same thing.

The distinction between *saturated boiling* and *subcooled boiling* has been made in some detail in the preceding discussion. The most common instance of saturated boiling is *pool boiling*, which occurs when a heater is immersed in a relatively large quantity of liquid which would be stagnant except for the natural convection currents set up by the heating. After an initial transient period during which the heat added brings the liquid to the boiling point, subsequent heat additional results in saturated boiling. If the liquid, subcooled or saturated, is forced to flow past the heated surface while it is partially or wholly evaporated, *forced convection boiling* is said to take place.

From the qualitative discussion which has been presented above, it may be seen that the subject of boiling heat transfer may be divided into two general areas: one, which is concerned primarily with conditions at or near the heating surface, includes nucleation, bubble growth, peak heat flux, and film boiling theory; the other, for heated or unheated channels with vapor and liquid in co-existence, is one of two-phase fluid flow and hydrodynamic instability analysis. Various aspects of these subjects will be examined in detail in succeeding articles, and both theoretical analysis and empirical correlations will be presented.

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PRACTICAL JUDGMENT IN DESIGN WORK

A man does not have to be in the business of ship or engine design for very long to realize that he is not dealing with neat little problems that can be first of all set up and then solved. The fact is that the nature of the problem itself may not be quite apparent until quite a lot of work has been done. In the design of an engine it could be said that the objectives to be aimed at would be such as reliability, low capital cost, low fuel cost, and so on. But to a large extent each one of these desirable qualities is increasable at the expense of the others, and the best sort of compromise may not be clear until the design is well advanced. The only way to be sure how long a certain component will last without attention is to try it out in service, and if it then proves to be inadequate considerable changes in the design may be called for. The job of designing a ship can be a lot vaguer still. Even if it has been definitely laid down that she must do the straightforward-sounding job of carrying a certain deadweight at a certain speed, there is still a lot of scope for difference of opinion as to what lay-out of ship is best. If the owner is turning over a number of different ideas in his mind, the design process can go on for a long time. The more vague the problem is, the more use must be made of past experience. It is quite a sound approach to avoid dealing with the design problem as a whole, but to take a successful past design and then incorporate in it such changes as are certain to be of benefit.

—SHIPBUILDING AND SHIPPING RECORD

"THE MOTOR SHIP"

MARINE DIESEL ENGINEERING IN 1960

ACKNOWLEDGMENT

This staff article was published in the January 1961 edition of "The Motor Ship."

THE GROWING ACCEPTANCE of Diesel engines in powers previously thought to be exclusive to the steam turbine is a most encouraging sign of the confidence in the reliabilty of the turbocharged, two-stroke engine of the modern designs but tends to obscure the steady progress made in other fields of Diesel engineering.

For some years now there has been a great interest in the possibilities of the medium-to-high-speed Diesel engine and although the year 1960 cannot have fulfilled all the aims of the protagonists of this class of engine there has been considerable consolidation of the position held by such machinery.

Developments now taking place in various engine works to enable these smaller Diesel engines to operate on residual grade fuels are of considerable value and where successful would appear to augur well for the future of this class of machinery.

THE NEED FOR REDUCED MAINTENANCE

Claims are so often made on behalf of the large-bore engines in terms of higher outputs and reduced specific fuel consumption that these factors often tend to obscure the equally important considerations of reliability, maintenance, weight and bulk. It has previously been pointed out in this journal that fractional gains in specific fuel consumption are not in themselves sufficient to sell engines deficient in other merits and that it would be wise for marine engine builders to restrain their endeavors towards still higher outputs to enable their designers to concentrate on other pressing problems.

In the past few years none could have failed to be impressed by the great advance made in Diesel engine outputs—powers made possible by the technique of turbocharging the large bore two-stroke engine—but some have sought consolation in the supposed lower reliability factor for the Diesel engine and in the considerable bulk and weight of the highest-powered engines. There is, however, sufficient disinterested evidence now available to show that the modern Diesel engine is inherently reliable and that breakdowns of such machinery are no more prevalent than for turbine-propelled vessels.

On the question of weight and bulk it must be conceded that the large Diesel engines present some problems which are now receiving the closest attention of Diesel engine designers; where heavy items must be removed care is now taken to see that this can be done in comparative ease and the move made by some concerns towards hydraulically-stressed nuts, studs and bolts with the provision of special

tools for shipboard use is undoubtedly a wise and, perhaps, overdue trend.

Developments concerning the slow-running engine types manufactured by Doxford, Sulzer, Burmeister and Wain, Stork and others have been announced during the year.

The Doxford P-type engine has attracted a great deal of attention in Great Britain and abroad and most of the major Doxford licensees have announced their intention of manufacturing this latest development. In the 560-mm and 670-mm cylinder bore types this engine should go far towards ensuring that the Sunderland concern has a growing share of the market for engines in the power range suitable for cargo vessels and the medium-sized tankers, while engines of even larger sizes of the P-type promise outputs suitable for all but the very biggest vessels contemplated. It is indicative of Doxford's continued confidence in the opposed-piston design that the P-type engine would not be unrecognizable to a marine Diesel engineer of 40 years ago.

Now with the same basic features but with considerable redesign to withstand higher loads and with the addition of exhaust gas turbocharging the first of the new P-type will soon be entering service in a Norwegian tanker and bearing in mind that it is this basic design which will bring Doxford engines into higher power ranges, its performance will be watched with interest.

Mention must also be made of the growing demand for the Sulzer two-stroke turbocharged engine of the R.D. type now built under license by practically all the major marine engine works in Britain. This design is a logical development of Sulzer's earlier S.A.D. and R.S.A.D. types and although the R.D. engine is available in a 900-mm-bore size it has so far proved to be a highly successful contender in the 760-mm-bore design which covers a power range of from 7,500 bhp to 18,000 bhp in engines of from five to 12 cylinders. As well as the popular 760-mm-bore design a 680-mm engine is also available while a 560-mm-bore design has been proposed.

So long as shipowners require higher powers from conventional slow-running machinery engine designers will be obliged to adopt higher pressures and the announcement from Burmeister and Wain of an m.i.p. increase to 9.5 kg/cm^2 for their turbocharged uniflow-scavenged engines of the VTBF types, previously rated at 8.0 kg/cm^2, typifies a general trend in this direction. This pressure increase means that B. and W. engines of the 620-mm-bore size can now be supplied for outputs of 1,080 bhp per cylinder or, alternatively, the larger bore units can cover the medium power range with less cylinders than hitherto.

This latter course has been adopted in the case of the Stork 750-mm-bore unit now being built by the Fairfield Shipbuilding and Engineering Co., Ltd., for their own account. As reported in this journal recently the Fairfield-Stork unit will be of the six-cylinder type developing 9,000 bhp at a bmep of 8.3 kg/cm^2 rather than an eight-cylinder unit developing 10,400 bhp at a bmep of 7.2 kg/cm^2.

While the intense development of the larger engines has been made with an eye on the tanker market, where high-output, single-unit installations would be in direct competition with steam turbine machinery, much of the data obtained with the experimental large-bore engines is directly applicable to the smaller engines suitable for more general applications, and probably ensures that the slow-speed types of marine Diesel engine will continue to hold their pre-eminent position for marine propulsion duties.

GROWING INTEREST IN HIGH- AND MEDIUM-SPEED ENGINES

However, it is significant to note also that continued progress is being made with the smaller high- and medium-speed Diesel engines which undoubtedly have a wide and growing field of application. Such progress has resulted in low specific fuel consumptions almost approaching those of the slow-speed engine types, low bulk/power ratios and correspondingly high power/weight ratios. There are, in fact, so many well-proven compact engines now available in this class that it would seem difficult to justify the adoption of steam machinery by some companies and authorities for such vessels as car/passenger ferries, fast fruit carriers and other ships of low dead-weight capacities requiring the maximum use of available space.

We recently visited the Pielstick engine-production facilities at the Ottensener Eisenwerk factory of the Willy H. Schlieker organization, in Hamburg, and were able to observe the high degree of interchangeability of components between various engines of this type.

There are some suggestions about reducing the number of engine types constructed in Britain to a few well-proven designs and, in this connection, it is interesting to note that Pielstick engine developments are carried out at the original design center in France, results of design changes and developments then being passed to the various licensees.

Pielstick engines entered service in several notable vessels during the year. Last January we published details of the 5,800-gross tons *Napoléon*, a passenger/vehicle ferry built at the La Seyne shipyard of the Atel. et Ch. de Provence for the Mediterranean services of the Cie. Générale Transatlantique (the French Line). In this vessel there are four Pielstick engines of the eight-cylinder in-line PC-type, turbocharged and coupled in pairs to the two propeller shafts. Each engine develops some 2,000 bhp and has an installed net power/weight ratio of only 33.7 lb/hp. Even more important for a vessel of this class is the low headroom required for

this engine installation. The *Napoléon* has a car deck running almost the whole length of the vessel interrupted only by the provision of watertight and fireproof bulkheads and a small casing for the engine uptakes. Above the car deck is accommodation for about 1,200 passengers in comfortable cabins, saloons and other public rooms, so that it is apparent that fullest advantage has been taken of the low height requirements offered by the class of machinery installed.

HEAVY-OIL BURNING DEVELOPMENTS IN 1960

Several other vessels of more than usual interest have entered service recently with Pielstick main propulsion machinery, but perhaps the most important development during 1960 with this design has been connected with the ability of Pielstick engines to operate continuously on heavy fuel. Mr. Robert Frederikson, technical director of the Johnson Line, of Stockholm, presented a paper to the October meeting of Scandinavian Naval Architects on the work his company has done in this field. Six vessels of the same class are involved, the first, *Rio de Janeiro,* now having completed more than 2,000 hours in operational service using a residual grade fuel, with, apparently, complete success. This is regarded as a major development for all operators of Pielstick machinery, as the Paris design bureau has issued notes on the methods employed and has cleared the engine for regular operation on this fuel. Provided efficient centrifuging and a correct degree of heating are employed there seems to be no reason why other makes of engine of this class should not operate with similar success on residual fuels.

At present there is no British licensee for the Pielstick engine but other designs of advanced type are being manufactured for various duties. One of the best known of these is the lightweight, high-speed Maybach engine, built by Bristol Siddeley, employed for rail traction duties in Great Britain.

The Maybach engine is one of the most interesting high-speed designs of recent years for marine applications by reason of its roller-bearing-mounted crankshaft, almost "square" cylinder dimensions and—in the case of the vee-engines of this range—the fork and blade type connecting rods employed to keep the length of the crankshaft as short as possible. In common with other engines of the high-power, lightweight type, all models of the engine share a common cylinder bore and piston stroke. Such size standardization obviously lends itself to a rationalized spares system.

AN INEXPENSIVE FRENCH ENGINE

During the year the French Société Alsacienne de Constructions Mécaniques announced their intention of seeking representation in Britain for the M.G.O. range of Diesel engines manufactured by S.A.C.M. at Mulhouse. Like the Maybach and some other designs the M.G.O. engine is a lightweight high-speed unit used initially for rail traction but which has now been suitably modified for marine duties.

The design of the engine is typical of many industrial units, being a four-stroke vee-type employing a rigid one-piece crankcase and frames, removable liners, light alloy pistons and pulse-pressure turbocharging with intercooling for engines in the higher output range. The engine length has been kept as short as possible by using a master- and articulated-connecting rod assembly. A four-valve cylinder head layout and efficient combustion chambers formed in the pistons contribute to the good thermal efficiencies attained. Again with this engine there is a large degree of part interchangeability of components: production line manufacture to rigid standards of inspection is said to ensure that performance ratings can be guaranteed. It is probably as a result of the large production run of this design—now used in locomotives, industrial power generating stations, the petroleum industry and latterly in French and Norwegian naval and merchant vessels—that the manufacturers are able to quote an ex-factory price equivalent to about £11 per h.p. Service ratings of the M.G.O. engine type range from 394 bhp for a vee-eight normally aspirated unit to 1,760 bhp for a turbocharged and intercooled 16-cylinder version with specific weights of 15.55 and 7.65 lb/hp respectively.

HIGH-SPEED UNITS FOR NAVAL VESSELS

However, a number of other well-known manufacturers are called to mind who have long been associated with lightweight engines—such old-established concerns as Mercedes-Benz, M.A.N., Fiat, Napier, Rolls-Royce and Paxman who have well-developed units of high performance available for marine duties and have also consolidated their position in the marine field during the past year. It is significant, however, that the majority of these engines were not designed as marine units from the outset, but have been adapted for marine use only after considerable proving has taken place in industrial applications. The old concept of massive proportions and great weight for marine engines is on the way out; it would seem that the shadow of the reciprocating steam engine has lain too long over marine engine drawing offices, and that the experience gained in other applications is now beginning to exert a considerable influence on the marine Diesel engine industry.

The year 1960 must be regarded as a year of consolidation for the high-performance lightweight engine, with several important new vessels now being ordered with this class of prime mover. We would mention in this respect the Napier Deltic installation ordered for a new Australian passenger/vehicle ferry, *Bass Trader,* Pielstick machinery for a new

Zim-Israel passenger cruising liner, Paxman YL-type engines for two new ferries for the Tilbury-Antwerp service of the British Transport Commission and the orders for Mercedes-Benz, Fiat and Deltic high-speed engines for naval vessels.

So far, mention has been made of engines differing in performance and design from the normally accepted concepts of marine Diesel engineering, but the development of more traditional designs has also been proceeding in a satisfactory manner during the year. Mirrlees, Bickerton and Day, Ltd., put into service the first of their new turbocharged, four-stroke Monarch-class engines last May in the distant-water trawler *Westella*. This engine has been specially designed for the fishing industry and demonstrates a good deal of careful planning to make this a reliable easily maintained unit. It is primarily a robust, lightly loaded engine notable for unusual but excellent facilities for withdrawing the pistons and connecting rods through the crankcase openings without disturbing the cylinder heads. Fuel consumption, at 0.34-lb/bhp-hr., must be regarded as most satisfactory and is undoubtedly due to good "breathing" made possible by a four-valve cylinder head layout.

A TWO-STROKE ENGINE FOR TRAWLERS

A new type of Crossley engine also entered service during the year in a British trawler, the *Woodleigh*. This is an eight-cylinder two-stroke turbocharged unit of the H.R.P. type, a development of Crossely's well-known H.R.N. design. Characteristics of the H.R.P.—previously installed in a coastal tanker—include the retention of a double-acting reciprocating scavenge pump working in series with the turbocharger and oil-cooled cylinder jackets and cylinder heads. This is a particularly neat and compact power unit of great robustness, eminently suitable for installation in small trawlers and tugs. The owners of this vessel have published information showing that the employment of a detergent-type lubricant for cylinder lubrication has contributed to lower wear figures and cleaner running.

In the *Woodleigh* the Crossley engine develops 550 bhp at 300 rpm being moderately boosted at only 22 per cent above the outputs of the normally aspirated units of well-proven H.R.N. design.

Apart from these important British additions to the range of Diesel engines suitable for low- and medium-power installations, M.A.N., in Germany have recently introduced a vee-form engine based on the GV series, widely employed for trawler, coaster and tug propulsion duties. The new engine, known as the VV series, is of the four-stroke, trunk-piston type built in normally aspirated or turbocharged forms with or without intercooling and built in 12-, 14-, 16- and 18-cylinder sizes for outputs of from 700 bhp to 2,530 bhp. Cylinder bore and piston stroke are common to all engines in the range being 300 mm and 450 mm respectively.

This engine is based on a deep welded foundation frame given added rigidity by cross tie-bolts between each cylinder. Other constructional features include the use of only four large-section cylinder head holding-down bolts; M.A.N. state that the rigidity of the head is more important for gas-tightness than the number of holding-down bolts employed. For overhauling, a maximum height of only 2.675 meters is required.

SMIT-BOLNES HEAVY OIL TESTS

During 1960 tests on heavy oil were carried out on an experimental single-cylinder Smit-Bolnes engine at the Kinderdijk works of L. Smit and Zoon under the auspices of the Laboratory for Combustion Engines of the Technical University of Eindhoven. This well-known uniflow-scavenged two-stroke engine employs individual scavenge pumps, which also act as crossheads, and because of the sealing glands between the working and scavenge cylinders is eminently suitable for heavy-oil operation. Although the fuel used for the test runs—which totalled several hundred hours' duration—contained 2.6 per cent sulphur, no trace of this was found in the crankcase oil while the combustion efficiency proved to be the same with either gas oil or heavy fuel.

DUTCH ENGINES TO BE BUILT IN BRITAIN

Another Dutch-designed engine in the news during 1960 was the Brons G.V. type which formed the subject of a license agreement between the Drypool Engineering and Drydock Co., Ltd., of Hull and Appingedam Brons Motorenfabriek of Appingedam, Holland. The Drypool company will manufacture Brons engines for coasters, tugs and trawlers, orders having been received for one 8G.V. type for re-engining a motor coaster and for two 12G.V. engines for two new trawlers.

These Brons engines are two-stroke types of vee formation with a cylinder bore of 220 mm and a stroke of 380 mm. Operation is on the uniflow scavenge system there being one exhaust valve per cylinder head and two turbochargers per engine. The normal operating speed is 320 rpm and the output per cylinder is 75 bhp. A fuel consumption of 0.348 lb/bhp-hr has been quoted.

The first British-Polar N-type engine entered service last year in the trawler *Philadelphian*. A report by Mr. A. Ekelund, chief engineer of Nydqvist and Holm, A.B., of Trolhattan, Sweden, was published in *The Motor Ship* for May, 1960, when some details of the development of this loop-scavenged, turbocharged two-stroke engine were given. In view of the previous comments on heavy oil burning in the smaller classes of engine it is interesting to note that heavy oil tests have been carried out on the N-type engine using fuels of up to 3,500 sec. Red. 1. viscosity. Although the single-cylinder

test engine employed was fitted with a cooled fuel injector nozzle and the fuel pipes were heated in the normal way, no other modifications have been required. We understand that further development is taking place with a view to introducing engines with higher degrees of turbocharging pressure to meet the ever-increasing demands for higher power outputs.

CONTINUING DEVELOPMENT OF THE FREE-PISTON ENGINE

One other class of propulsion machinery which continues to attract attention is the free-piston engine operating in conjunction with the gas turbine driving through reduction gearing.

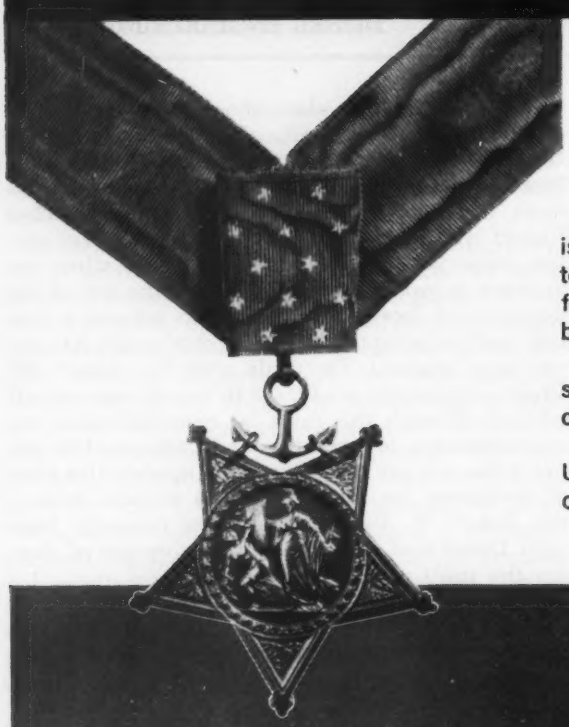
No serious problems face the turbine designers; the low temperatures and pressures involved permit the use of conventional materials and design features and there seems to be no reason why the turbine side of this plant should not give better efficiency than is generally obtained, and approach 100 per cent reliability. The Mk. II version of Power Jets gas turbine, built by Rankin and Blackmore and installed in the Dutch whale-catcher *Robert W. Vinke*, features an improved astern section shrouded to reduce windage losses when the machine is running ahead. Although the aim of the designers of free-piston plant is to achieve a specific fuel consumption of 0.4 lb/shp-hr this has not yet been attained. On trials with the *Robert W. Vinke* a consumption of 0.418 lb/shp-hr was recorded and although this must be regarded as an encouraging step towards the 0.4 lb consumption figure it has not yet been possible to operate this class of machinery for long periods on residual fuels—the *Robert W. Vinke* will in fact normally burn light Diesel fuel and was operating on gas oil during the trials runs.

Official U. S. Coast Guard Photos

Admiral Will, Principal Banquet Speaker flanked by the Chief of Naval Operations and the President of the Society.

A propulsion system using twin Solar Saturn gas turbines of 2200 hp has been ordered by the Coast Guard for installation in a new 82-ft. patrol boat, now being built at Curtis Bay, Md., for high speed search and rescue operations. The variable speed engines will drive controllable pitch propellers. Throttle and propeller control will be synchronized into one control unit. Previous boats of this type have been powered by twin 600 hp diesels. The Saturn engines each weigh 1200 lb. as compared to about 6500 lb. for diesel engines, and occupy less than 15 cft against 120 cft.

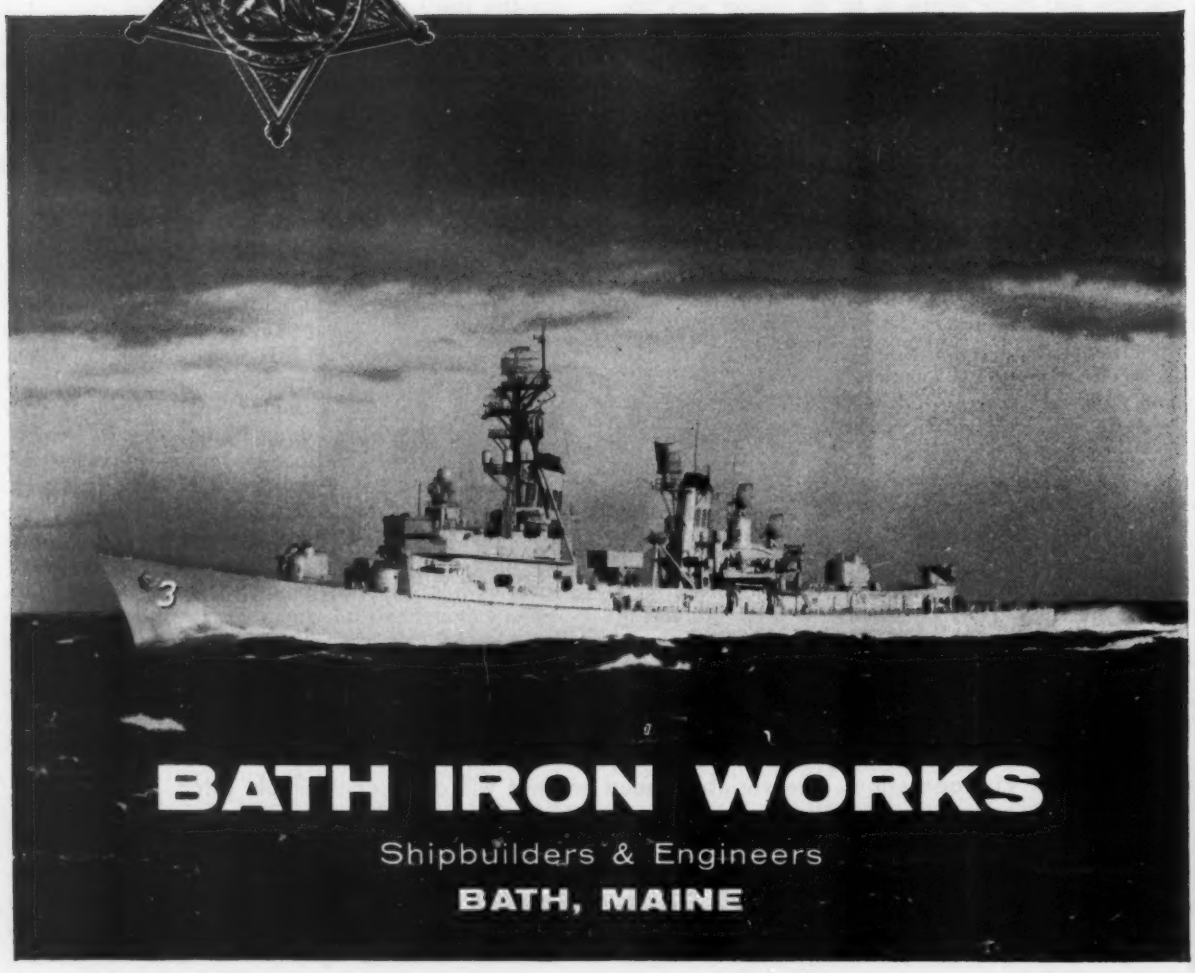
—MARINE JOURNAL



The Medal of Honor, the country's highest decoration, is presented by the President in the name of Congress to members of the Armed Forces of the United States for gallantry and intrepidity, at the risk of life, above and beyond the call of duty.

Chief Water Tender John King, U.S.N. was, on two separate occasions, awarded the Medal of Honor — one of only seven Navy men in our history so decorated.

The Navy's newest guided missile destroyer, the U.S.S. JOHN KING (DDG3), named in his honor, was commissioned at Boston on 4 February 1961.



BATH IRON WORKS

Shipbuilders & Engineers

BATH, MAINE

R. W. PEACH

CONCERNING THE RELATIONSHIP BETWEEN POSSIBLE EXCITATION MODES AND THE HARMONIC COMPONENTS OF AN INPUT FORCE

THE AUTHOR

received his B.S.E. in Naval Architecture and Marine Engineering from the University of Michigan in 1944. Upon graduation he worked for two years in the Central Technical Department of Bethlehem Steel Company, Shipbuilding Division, Quincy, Massachusetts. After a year of military service, he returned to the University of Michigan to do graduate work and earned an M.S.E. degree in Engineering Mechanics. In 1950, he went to Reaction Motors, Inc., Dover, New Jersey, to work on rocket engines. Two years later, he joined Electric Boat Division, General Dynamics Corporation, in the Marine Engineering Department. At present, he is Chief Engineer on the S3G/S4G Power Plant Project for the USS TRITON.

IT FREQUENTLY happens in a vibrating system such as a propeller shaft of a ship that a variable input force will arise from a variable field such as wake (see Figure 1) on the input link to the system, the propeller. The question arises as to whether and how much of this force from the wake is effective in exciting the system. If this force is known and the damping of the system is known, then it is possible to determine how serious the resulting vibration will be.

The following discussion is based on the example of a propeller shaft, propeller, and wake system but is general and can be applied to any system. The question of whether the wake of itself represents the excitation to the system will not be discussed, but, for convenience, it will simply be assumed to be the input force.

Two different approaches to the problem are possible—intuitive and mathematical. For those who are satisfied with the intuitive method, this method will be used. For those who wish a more substantial answer, the mathematical method will be presented also.

It is assumed that only harmonic inputs can excite and sustain a vibration. In the sustained vibration, the amplitude will depend on the amount of

damping and size of input force. Therefore, in the variable wake it will be necessary to find the amplitudes of the harmonic components. The method of obtaining the harmonic components will not be covered as it can be found in standard references [1], [2].

Assume that the wake of Figure 1 has been harmonically analyzed and the fundamental force amplitude has been obtained (Figure 2). Assume a three-blade propeller has been installed on the ship.

Figure 2 shows how the blades will be affected by the forces. If the propeller is considered rigid, then the net force on the three blades must be sinusoidal to excite the shaft system. If the vibration is torsional or longitudinal, it is excited by a force. If the vibration is whirling, one must be careful to use a moment or couple on the propeller.

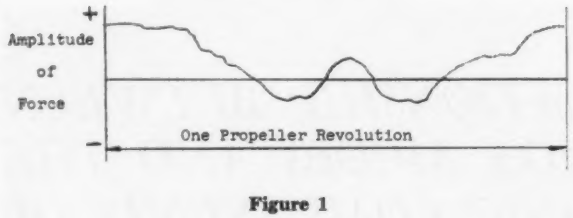


Figure 1

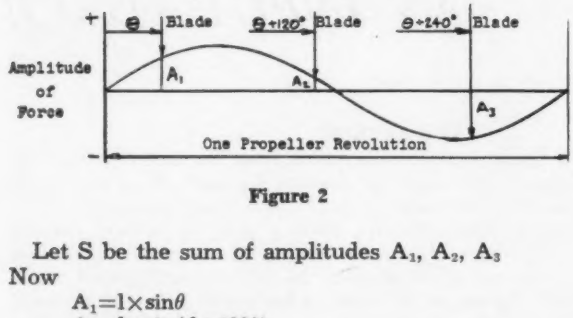


Figure 2

Let S be the sum of amplitudes A_1, A_2, A_3
Now

$$A_1 = 1 \times \sin\theta$$
$$A_2 = 1 \times \sin(\theta + 120°)$$
$$A_3 = 1 \times \sin(\theta + 240°)$$

where the amplitude of the sine curve has been taken as unity for simplicity.
From which

$$S = \sin\theta + \sin(\theta + 120°) + \sin(\theta + 240°)$$
$$S = \sin\theta + \sin 120° \cos\theta + \cos 120° \sin\theta + \sin 240° \cos\theta + \cos 240° \sin\theta$$

$$S = \sin\theta + \frac{\sqrt{3}}{2}\cos\theta - \frac{1}{2}\sin\theta - \frac{\sqrt{3}}{2}\cos\theta - \frac{1}{2}\sin\theta$$

This results in

$$S = 0$$

Which implies that there is no harmonic input into the system from the fundamental with a three-blade propeller.

Maybe the second harmonic will excite the system. Let us try the second. Figure 3 shows the three-blade propeller on the second harmonic curve.

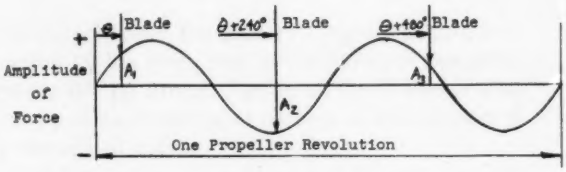


Figure 3

It should be noted that with the second harmonic there are 720° in one propeller revolution and, therefore, the blade spacing relative to the harmonic is 240°. As in the case of the fundamental, the sum of the amplitudes of the forces can be written:

$$S = \sin\theta + \sin(\theta + 240°) + \sin(\theta + 480°)$$

However,

$$\sin(\theta + 480°) = \sin(\theta + 120°)$$

So the above expression reduces to the same results as obtained for the fundamental. Thus

$$S = 0$$

and the second harmonic cannot excite the system.

In a like manner, let us proceed to the third harmonic as shown in Figure 4.

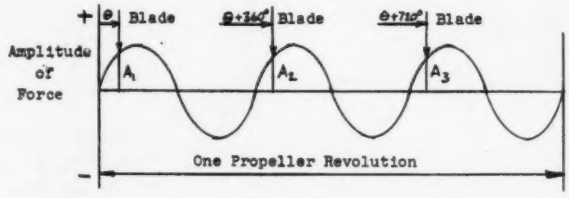


Figure 4

As in the case of the second harmonic, one revolution of the propeller represents more than one cycle of the harmonic. In this case, it amounts to three cycles with the blade spacing being 360°. Thus

$$S = \sin\theta + \sin(\theta + 360°) + \sin(\theta + 720°)$$

But

$$\sin(\theta + 720°) = \sin(\theta + 360°) = \sin\theta$$

And

$$S = 3\sin\theta$$

We have finally obtained an harmonic input, and it is three times the amplitude of the harmonic curve.

Intuitively it follows that the fourth and fifth harmonic will not give an harmonic input to the system, but the sixth will. The same reasoning can be applied to the higher harmonics, and to other numbers of blades. This leads to the conclusion: *Only those wake harmonics which are integer multiples of the number of blades can excite a thrust or torque variation and the order is the harmonic times the shaft RPM.*

In order to find the couple acting on the shaft, re-examine the above expressions and it will be seen that the fundamental produces a couple equal to the amplitude of the harmonic times

$$(\sin\theta+\frac{\sqrt{3}}{2}\cos\theta)$$

times the diameter of the circle of applied resultant thrust on a propeller blade. The same is true for the second harmonic. It should be noted that,

$$\text{Sin}\theta+\frac{\sqrt{3}}{2}\cos\theta=\sqrt{1+\tfrac{3}{4}}\ \sin(\theta+\varepsilon)$$

Where $\text{Tan}\varepsilon=\dfrac{2}{\sqrt{3}}$

However, the third harmonic does not produce a couple. The following conclusion is drawn: *All wake harmonics which are not integer multiples of the number of blades excite a couple type variation, and the order is the harmonic times the shaft RPM.*

For those who desire a more rigorous solution to the above problem, the following is presented:
Assume:

(a) The sum of the axial or tangential forces on each blade must be a sinusoidal force to produce a thrust or torque excitation.
(b) It is possible to add a sine and cosine term vectorally to represent a displaced sine curve.
(c) The wake is periodic on one revolution of the propeller.

Let m = the harmonic
n = the number of blades
ϕ = the blade interval in terms of the harmonic interval A-B of Figure 5
θ = the position of the first blade
Then

$$\phi n=2\pi m=360^\circ \text{ of propeller rotation}$$

The blades will be located at

$$\theta,\ \left(\theta+\frac{2\pi m}{n}\right),\ \left(\theta+2\frac{2\pi m}{n}\right),\ \ldots\ \left(\theta+n\frac{2\pi m}{n}\right)$$

Where $\left(\theta+n\dfrac{2\pi m}{n}\right)$ is the first blade included to cover the summation for one complete revolution. The force amplitudes are

$$\sin\theta,\ \sin\left(\theta+\frac{2\pi m}{n}\right),\ \sin\left(\theta+2\frac{2\pi m}{n}\right),\ \ldots\ \sin\left(\theta+n\frac{2\pi m}{n}\right)$$

The total force is then

$$S=\sin\theta+\sin\left(\theta+\frac{2\pi m}{n}\right)+\sin\left(\theta+2\frac{2\pi m}{n}\right)+\ \ldots$$

$$\ldots+\sin\left(\theta+n\frac{2\pi m}{n}\right)$$

or

$$S=\sum_{K=0}^{K=n}\sin\left(\theta+\frac{2\pi Km}{n}\right)$$

Since K is an integer, it follows that, if
$m=\lambda n$

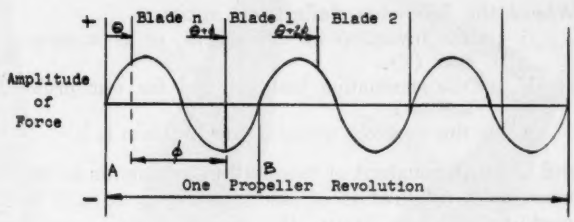


Figure 5

where λ is an integer, the above expression reduces to

$$S=(n+1)\sin\theta$$

or the thrust and torque are harmonically varying.

It appears from the above expression that the amplitude is (n+1), but this is not so, as, in order to complete the revolution of the propeller, the first blade was counted twice. Therefore, the force amplitude is n times the amplitude of the harmonic curve.

The above was relatively easy, but proves only a half of the problem. Suppose $m\neq\lambda n$ where λ is still an integer, then it is necessary to evaluate the sine and cosine series sums. The method used to evaluate these series is that of the calculus of finite differences. Many of the readers may recall from their elementary calculus the fundamental theorem, namely,

$$\frac{dy}{dx}=\lim_{\Delta x\to 0}\left[\frac{f(x_o+\Delta x)-f(x_o)}{\Delta x}\right]$$

Maybe the reader considered what would happen if Δx were not allowed to approach zero. Most of us, however, were so busy with other courses that we could not stop to investigate this problem. Nevertheless, as will be seen, it does have some interesting uses. When Δx is kept finite, rather than allowed to approach zero, we have the fundamental theorem of the calculus of finite differences. In a manner analogous to that of calculus, there is an inverse to the differences, which is summation. There is then the following relationship:

Infinitesimal Calculus	Finite Difference Calculus
Differentiation	Differences
Integration	Summation

Not all functions can be summed directly. However, in the present problem we are in luck because both sine and cosine functions can be summed, and, similar to the table of integrals, there is a table of summation expressions [3] from which is obtained:

$$\Delta^{-1}\sin(ax+b)=\frac{-h\cos\left(ax+b-\dfrac{ah}{2}\right)}{2\sin\dfrac{ah}{2}}+C$$

Where the following definitions apply,

Δ^{-1} is the inversion of differences, or is summation (Σ).

h is the summation interval and for our problem is 1.

x is the variable which in our problem is k.

and C is the constant of summation analogous to the constant of integration of calculus. Since we will be working between limits, this constant will cancel out of the answer just as in calculus when integrating between limits.

In the expressions we have, it is seen that

$$b=\theta$$

$$\text{and } a=\frac{2\pi m}{n}$$

Substituting these values into the general summation expression gives:

$$\sum_{K=0}^{K=n}\sin\left(\theta+\frac{2\pi km}{n}\right)=\frac{-\cos\left(\frac{2\pi km}{n}+\theta-\frac{\pi m}{n}\right)}{2\sin\frac{\pi m}{n}}\Bigg|_{K=0}^{K=n}$$

$$=\frac{-\cos\left(2\pi m+\theta-\frac{\pi m}{n}\right)+\cos\left(\theta-\frac{\pi m}{n}\right)}{2\sin\frac{\pi m}{n}}$$

As m is an integer, this reduces to

$$\sum_{K=0}^{K=n}\sin\left(\theta+\frac{2\pi km}{n}\right)=\frac{-\cos\left(\theta-\frac{\pi m}{n}\right)+\cos\left(\theta-\frac{\pi m}{n}\right)}{2\sin\frac{\pi m}{n}}$$

or

$$S=\sum_{K=0}^{K=n}\sin\left(\theta+\frac{2\pi km}{n}\right)=0$$

which proves the second half of the problem. Examining the next to last expression above, it will be observed that the amplitude of the couple will be the amplitude of the harmonic curve times the cosine of the angle of blade spacing times the diameter of the circle of the center of blade thrust.

From the above discussion we have these conclusions:

(a) The results are general and can be applied to any similar mathematical system.

(b) Assuming a wake variation, only those wake harmonics which are integer multiples of the number of blades can excite a thrust or torque variation and the order is the harmonic times the shaft R.P.M. The amplitude is the number of blades times the amplitude of the harmonic.

(c) All wake harmonics which are not integer multiples of the number of blades excite a couple type variation, and the order is the harmonic times the shaft R.P.M. The amplitude of the couple is the amplitude of the harmonic times the cosine of the angle of the blade spacing times the diameter of the circle of the center of thrust on the blades.

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[2] Willers, Dr. Fr. A., *Practical Analysis, Graphical & Numerical Methods*, Dover Publications, Inc., 1948.

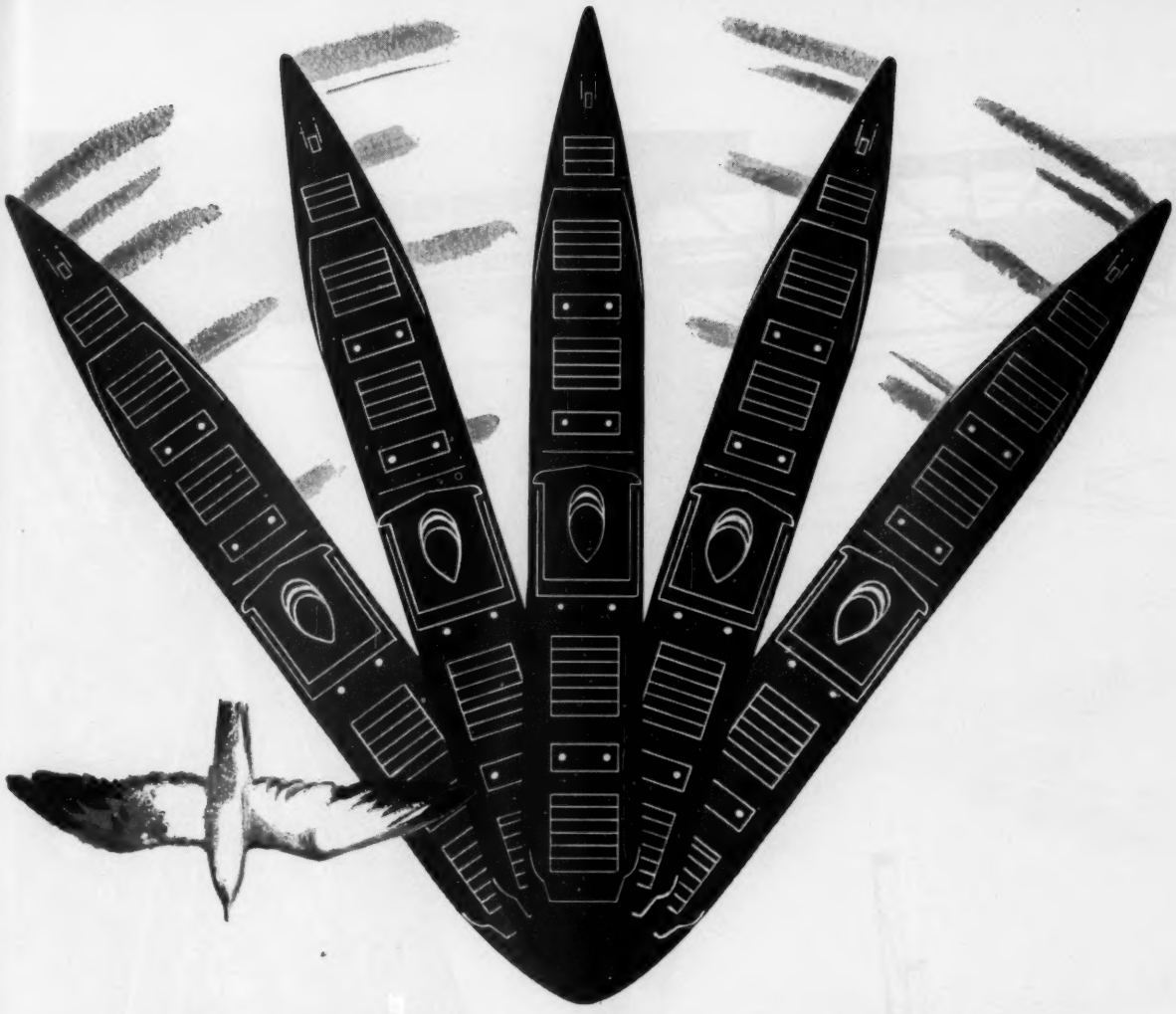
[3] Jordan, C., *Calculus of Finite Differences*, Chelsea Publishing Company, 1947.

The Secretary of the Navy on 14 December 1960 approved, for legal purposes, the abandonment of the ***US Cairo***, Civil War gunboat of the Union Navy. ***Cairo*** was sunk in the Yazoo River, near Vicksburg, Mississippi, by a Confederate torpedo (mine) in December 1862.

The legal abandonment of ***Cairo*** clears the way for private operations to raise the entire ship for preservation purposes. Interested individuals have previously raised portions of ***Cairo***.

The salvage and preservation of ***Cairo*** is of timely public and Naval interest in view of the Civil War Centennial currently being celebrated. It appears that ***Cairo*** was the first warship sunk in the Civil War by a torpedo and that it is the only Civil War ironclad remaining in a preserved condition.

—from BUSHIPS JOURNAL
April 1961



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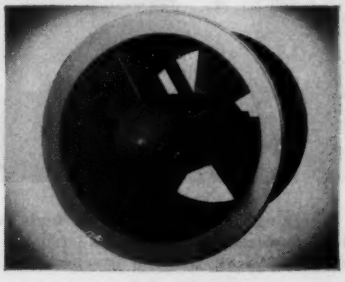

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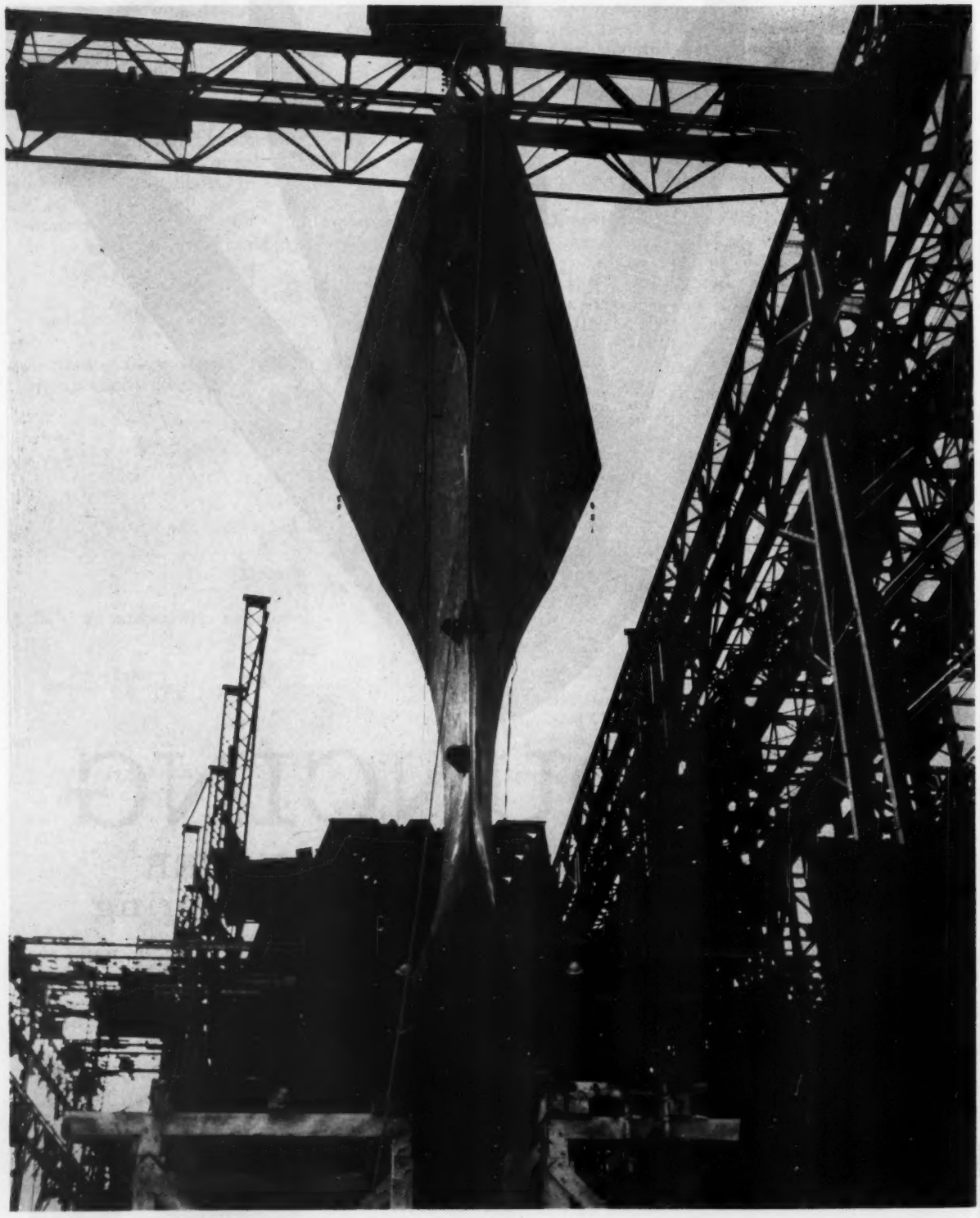
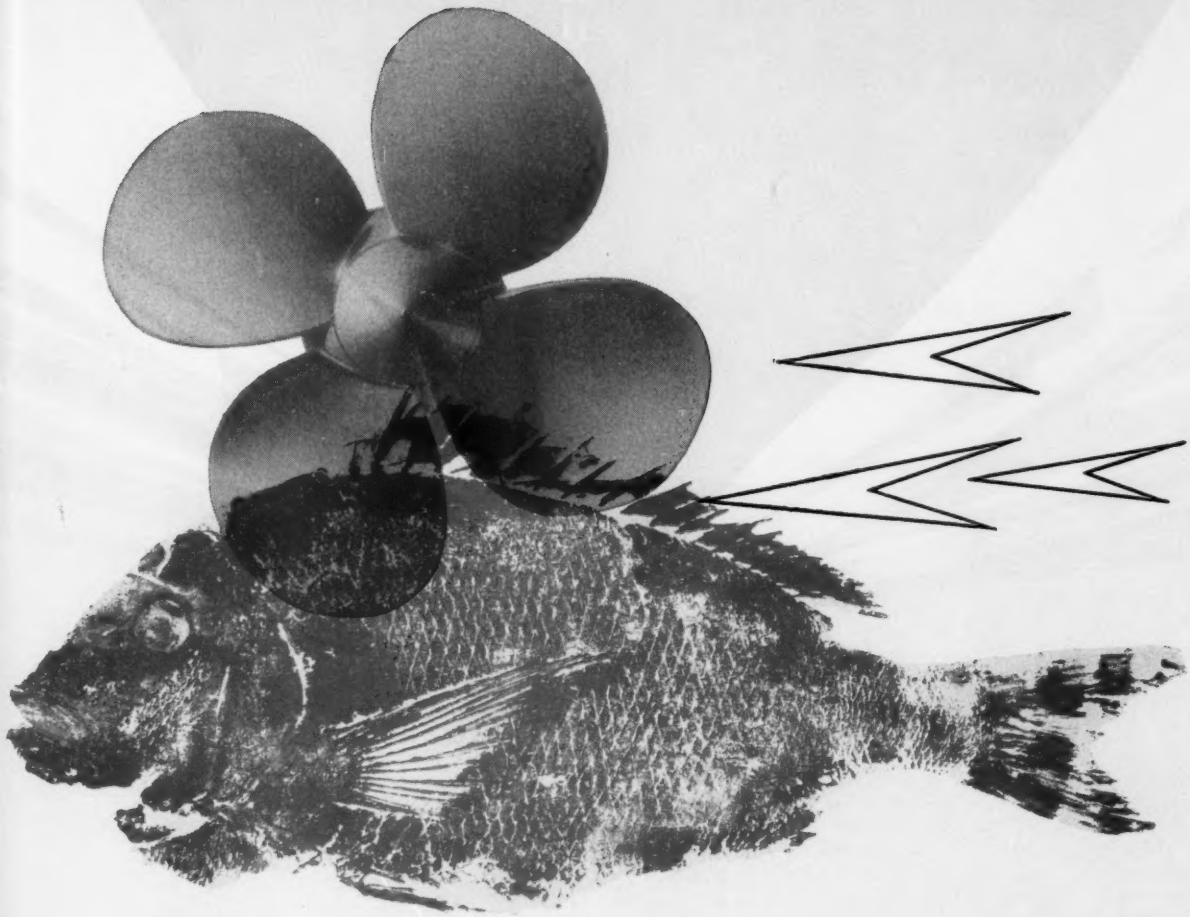


Weighing 59 tons, this 47 ft. high bow section is hoisted into position for welding to the hull of the U.S. Navy's first nuclear powered, guided missile frigate *Bainbridge* which is under construction at Bethlehem Steel Company's Quincy Shipyard. The sleek warship is scheduled to be launched in April.



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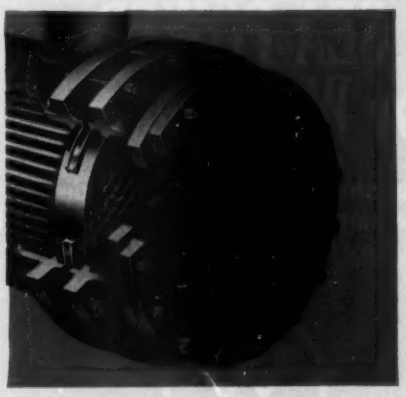

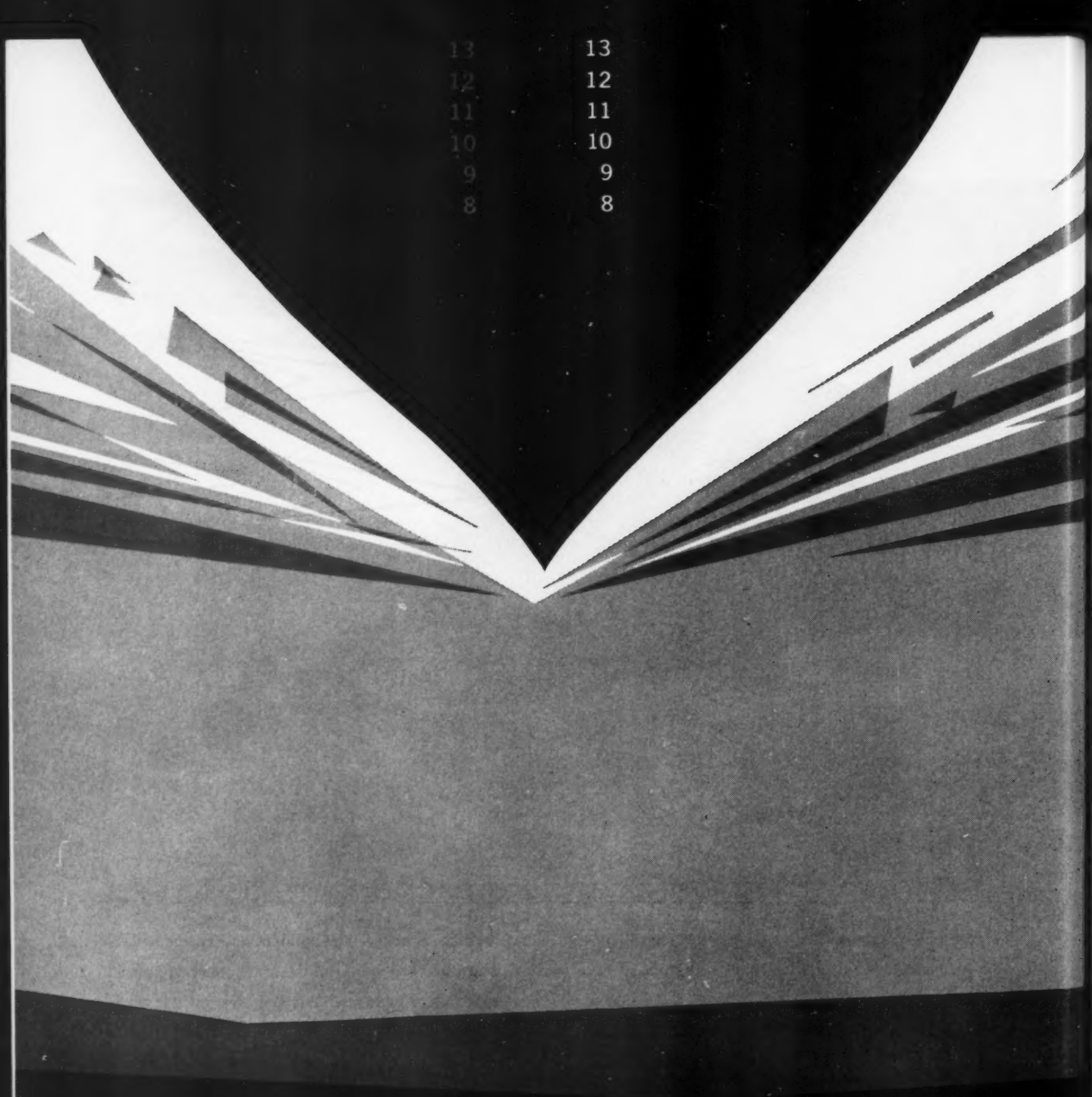

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VALUE ENGINEERING ON THE LPD

THE AUTHORS

Mr. Johnson was in the Bureau of Ships office of Value Engineering from February 1955 until November 1960. Prior to this, he was employed for four years in the Special Projects Section of the Turbine and Gear Branch of the Bureau of Ships. Before coming to the Bureau, he was assistant to the Chief Engineer at Briggs Filtration Company, a field engineer for steam turbine installation with the General Electric Company and a design engineer for Reynolds Metals and Solvay Process Company. He completed a specialized course in Mechanical Engineering in 1941 at the University of Pittsburgh and a four year course in Business Administration-Management, at Southeastern University in 1959. During World War II he served as a fighter pilot in the U.S. Air Force. At present he is Manager of New Programs for Washington Technological Associates, Inc.

Mr. Schuler has been in the Value Engineering Office of the Bureau of Ships since December 1954. He spent four years as a Naval Architect in the Preliminary Design Branch of the Ship Design Division of the Bureau. Prior to this he was a Boiler and Machinery Insurance Underwriter for the Columbia Casualty Company. He received his B.S. degree in Naval Architecture and Marine Engineering from Webb Institute in 1947 and was a Naval Architect with the Tacoma Boat Building Company. He also holds an L.L.B. degree from the George Washington University. He is a registered professional engineer in the District of Columbia and a member of ABA, ASE, ASNE and SNAME.

THE BASIC PREMISE of Value Engineering is that an intensive study of function versus cost can save a lot of money. The validity of this premise has been proven many times. It has been applied to parts, sub-assemblies, systems and whole ships. We intend to show how this applied in the study of the LPD by a Task Group at the New York Naval Shipyard. We will do this by describing the Value Engineering Study of LPD, by listing some of the items studied, by drawing a few conclusions from the facts presented and mentioning some of the factors which made it a success.

The Value Engineering study of this ship was unique in many ways. It was one of the most concentrated value engineering efforts on a single ship since the beginning of the Bureau of Ships' Program in 1954. It involved cooperation among the forces of the fleet, the shipbuilder, the Bureau of

Ships and other interested parties. It illustrates how much can be done to reduce cost even on a design where cost is emphasized throughout its evolution.

The story of this study began after the Preliminary Design Branch of the Bureau had proven the feasibility of the design. A thirteen page set of ship characteristics had been prepared. The Contract Design Branches defined the ship with fifty drawings and a 595 page specification. The configuration of the ship at this stage is shown in the artist's concept (Figure 1).

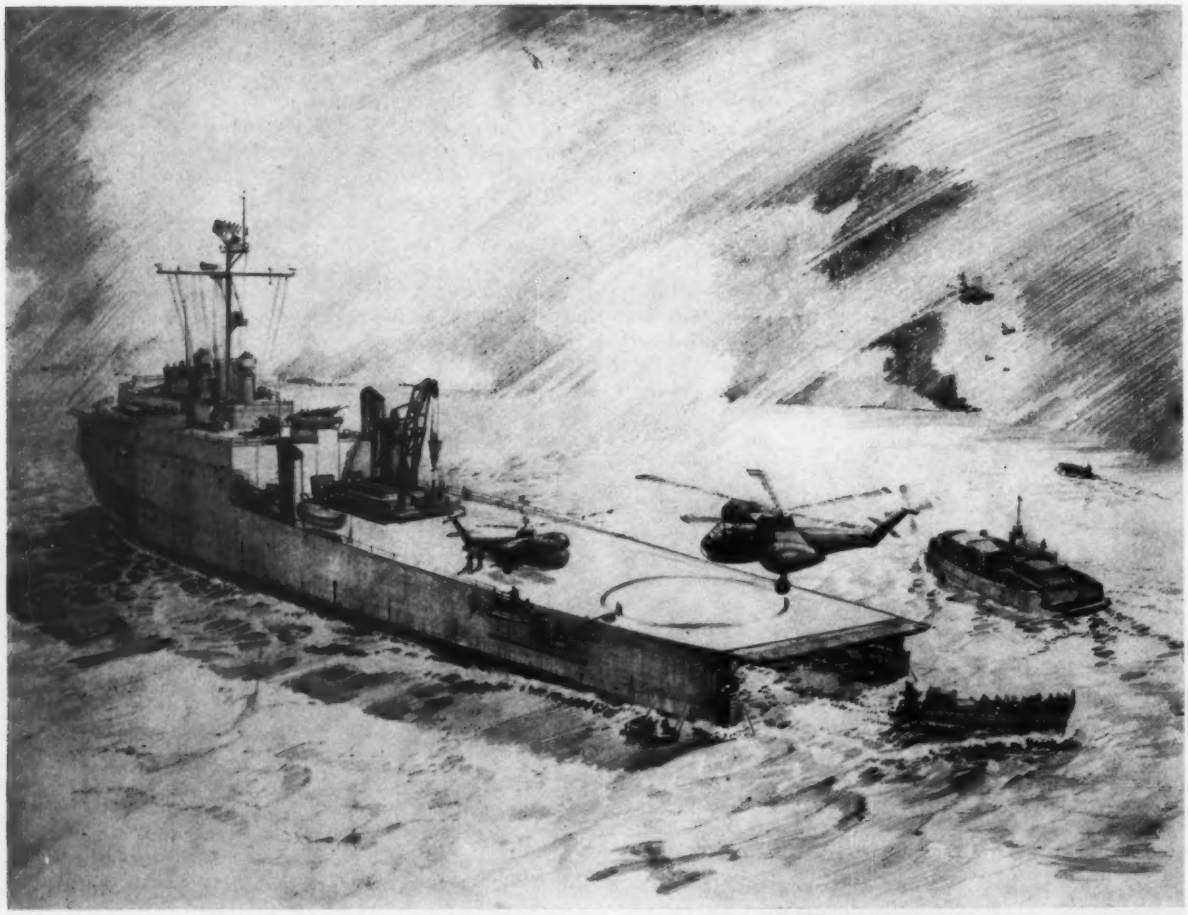
WHAT IS AN LPD?

The LPD is an Amphibious Assault Ship. Its hull form is comparable to the LSD (Landing Ship, Dock). It has a length of 500 feet on the load water line and a beam of 84 feet. It displaces 7,500 tons of salt water in light condition and 13,820 tons in full load condition. The full load draft is 20 feet. It has two screws with 12,000 shaft horsepower on each.

The basic function of the ship is to carry cargo. It has been stated that the cargo handling gear is the main battery of this ship. The cargo can be offloaded either by helicopter or by landing craft. It has a flat deck aft for handling helicopters. The stern gates open to accommodate the landing craft.

PURPOSE OF THE TASK GROUP

When the LPD-1 was assigned to New York, the Shipyard Commander, Rear Admiral S. N. Pyne, decided to exert more than usual effort to build it at minimum cost. The first major step was taken on 2 March 1959 when the Planning Department at New York issued an instruction "to establish a Value Engineering Task Group in the Design Division to analyze the design of LPD-1 to insure minimum cost." Of course, the Naval Shipyard had a trained and competent full-time staff available to lead this



"Official United States Navy Photograph."

Figure 1. Artists Concept of the LPD-1. Built essentially on the LSD-28 Type Hull, the LPD carries heavier cargo transported by boat with some helicopter capability. It represents a much smaller version of the APA-M concept. The well is about one-third of that of the LSD permitting the remaining space to be utilized for storage of vehicles and cargo. This ship is able to carry more troops than the LSD-28 Class.

task group.* For this study, the regular staff was augmented by the loan of engineers from the hull, machinery and electrical-electronic design groups in the yard. The road was paved for this group by giving the above instruction wide circulation within the Design Division and throughout the Naval Shipyard.

The task group was established to operate for two months. The follow-up action on its proposals would then devolve on the regular local Value Engineering Staff. The task group actually functioned for three months under the direction of Commander D. H. Jackson, the Design Superintendent. The efforts of the task group were augmented by a short term contract with George Sharp, Incorporated, a design agent in New York. Mr. B. Teichez acted as the Chief Consultant for George Sharp, Incorporated. The design agent agreed to study the ship and suggest areas where commercial marine components could be used in lieu of Navy standard components to provide the needed functions at less cost. The proposals of the design agent were handled by the task group in the same manner as all other proposals. Several of the projects suggested by George Sharp, Incorporated, are included in the list of projects discussed later.

The whole task group made a trip to the Amphibious Operating Base at Little Creek, Virginia on the 24th and 25th of March 1959.** They visited two ships of the LSD type. The purpose of this trip was to gain familiarity with the type of ship under study and to discover areas of poor value. Through observation and conversation with ships' personnel, the task group began compiling a list of potential projects. As the study progressed, some of these potential projects were deleted and some new ones were added. This list always represented more work than could be handled in the alloted time. This situation is normal in Value Engineering and it meant that the task group could be selective about their projects.

BUREAU OF SHIPS COOPERATED

On 31 March 1959 an unusual step was taken. The Landing Ship Type Desk issued a memorandum to all of the design and technical codes of the Bureau of Ships. This memorandum alerted these people to the existence of the LPD study, the types of proposals to be expected and the need for expeditious handling of replies to these proposals. It also set up special procedures to obtain fast action. In many cases, action was taken on these proposals within days or even hours of their receipt in the Bureau. A large part of the credit for this speed must go to Mr. Haas and Mr. McDuffee of the Landing Ship Type Desk which acted as Bureau Coordinator for this ship.

At the other end of the line, New York Naval Shipyard was holding weekly meetings of the Design Division Review Panel. This panel included the Head of the Value Engineering Task Group, the Design Superintendent, Chief Design Engineer, Deputy Chief Design Engineer and the Assistants for Hull, Machinery and Electrical Design. These meetings were held to review progress, overcome potential roadblocks, and establish schedules for taking action on design changes. The task group study was proceeding simultaneously with the design development so that good coordination was essential for success.

SPECIFIC PROPOSALS MADE

With the administrative groundwork laid, the Value Engineering Task Group began developing projects. They began submitting specific proposals to reduce the cost of this ship. These proposals were made in the form of Value Engineering project reports. An example is shown in Figure 2. This illustration shows the project report form which includes sketches, background information, a brief proposal and the results together with certain administrative information. A project report is normally prepared for each Value Engineering Project. It functions as a vehicle for briefing the project, as a record of work done, as an enclosure to a letter requesting action and as a means of cross-fertilizing ideas among shipyards engaged in the Value Engineering Program.

A report such as that shown on Figure 2 was prepared for each of the projects studied by the Value Engineering Task Group. These projects covered a wide variety of subjects. The following is a brief statement of some of the proposals made, the actions taken and the estimated savings.

THERMAL INSULATION REVIEWED

There are two basic types of hull thermal insulation used aboard naval ships today. One type is a fibre glass mat which is fitted in place and then covered with a brattice cloth facing. The other type has a facing material attached to the mat in the manufacturer's plant. It would appear to be less expensive to install faced board on large flat plane surfaces. Unfaced board would appear to be easier to fit in areas when the bulkhead has frequent penetrations for pipes, etc. As a matter of fact, the difference depends more on the local labor rates for installation. On the LPD, New York obtained bureau approval to use the hard-faced fibre glass board and saved an estimated $62,850. New York was already using the newly developed hull thermal insulation fasteners.

*The Value Engineering Staff at New York Naval Shipyard consisted of Messrs. C. T. G. Murphy, F. Hunter, A. Zanetti, and A. Rosenfield. The Task Group also included Messrs. D. Beges, C. F. Granilone, A. H. Wahlers, H. J. Stracheski, and F. Devine.

**The Task Group was accompanied by Commander Shor, the Assistant Design Superintendent at New York; four representatives of George Sharp, Incorporated; Mr. J. Haas, representing the Landing Ship Type Desk of the Bureau of Ships; and Mr. R. Johnson and Mr. Schuler of the Value Engineering Office.

VALUE ENGINEERING PROJECT REPORT NAVSHIPS 4629 (REV. 11-58) (Front) BUDGET BUREAU NO. 45-R-285 NAVSHIPS REPORT 4650-1

PREPARING ACTIVITY	SIGNATURE OF RESPONSIBLE AUTHORITY	DATE
New York Naval Shipyard	C. T. G. Murphy	22 Apr 1959

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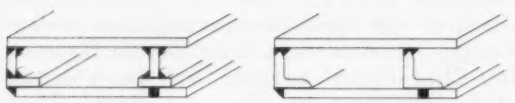
SKETCHES OF BEFORE AND AFTER

Stiffners on Water Barrier Panels in Well of LPD-1



Before After

FOLD ON THIS LINE

DATE RECEIVED	SOURCE	DATE STARTED	INVESTIGATOR
3 April 1959	A. W. Wahlers	3 April 1959	A. W. Wahlers

BACKGROUND

Water Barrier Panels are installed in the well to dampen wave action when the well is open to the sea. CONTRACT DRAWING LPD-800-1934022 shows the stiffners for the water barrier panels constructed of built-up Tees and Angles. Fabricating these structural shapes from flat bars requires two 3/8" fillet welds. The resultant Tees and Angles must then be straightened and welded into the panels. Two panels are 7'x25"; eight panels are 7'x8'.

PROPOSAL

Use 3"x2"x7/16" angles (shear 3/16" off of the 3" leg) in lieu of stiffners fabricated from flat bars.

This eliminates 1100 feet of 3/8" double fillet weld and straightening of the built-up stiffners.

RESULTS

Approved by the Design Division Review Panel on 4/9/59 for local adoption by Code 250.

Save on 25' panels: 2x$325.00 = $650.00
Save on 8' panels: 8x$218.75 = 1750.00
Total Savings = 2400.00

SHIP	ACCOUNT NO.	SERIAL NO.	SUBJECT	STATUS AND DATE	APPLICATION	SAVINGS
316	131	29	Stiffners on Water Barriers	CA 4/22/59	LPD-1	$2,400

Figure 2. Using commercial angle stiffeners on the Water Barrier Panels in the Well of the LPD. (This illustrates the use of the Value Engineering Project Report Form.)

The specifications for the LPD originally called for the use of standard Navy insulation for reefer spaces. The use of commercial marine insulation was proposed. Specifically, reeferite lining and ceiling, dexotex flooring and commercial doors were suggested. The savings were estimated as $50,000 per ship and the project received the approval of the Bureau of Ships.

ALTERNATE MATERIALS USED

The material used for the vertical and inclined ladders was changed from aluminum to steel. New York Naval Shipyard had the dies for making steel ladders. The parts could be cut with oxyacetylene torches and welded by the electric arc method. Aluminum ladder parts would have been cut on a band saw or nibbler and welded by the slower more costly, heliarc method. Then, too, the attachment of steel ladders to steel structure was simpler and cheaper. The nominal weight increase was accepted when the Bureau approved this project. The savings will exceed $5,000.

One project aimed at finding a less expensive substitute for the cast propeller shaft struts and barrels. It was estimated that $7,000 could be saved by fabricating the shaft barrels from plate. The struts could be rolled from bar stock and welded to the barrel assembly. This substitution was approved locally.

As originally designed, the water barrier panels were stiffened by welding 7/16" (17.85#) flat bars as shown in Figure 2. Commercial 3" x 2" x 7/16" angles were substituted for the flat bars in the ends of the panels. This eliminated 1100 feet of ⅜" double fillet welding. It obviated the need for straightening these stiffeners after sub-assembly. This substitution was approved locally and saved $2,400 on the LPD-1.

The contract design required angle stiffeners on the sides, top and bottom of the shaft tunnels. These shaft tunnels pass through the ballast tanks. It was originally suggested that stiffeners cut from plate be used. Further study proved that the curved top of the shaft tunnels did not need stiffening. (Figure 3) Local approval of this project saved $1,000.

Several interesting proposals concerning these shaft tunnels were reviewed. One idea was to use a circular cross section and delete all stiffeners. This was abandoned because it would infringe too much on the ballast tank volume.

Large saving resulted from the proposal to use 10 pound STS plating protection for the deckhouse in lieu of the specified 30 pound STS. The Bureau approved this change and saved 65 tons of weight as well as $59,772.

The Bureau of Ships policy requires galvanizing of wet, inaccessible places bounded by relatively thin or highly stressed shell plating. In view of the fact that the inner bottom in the machinery spaces on this ship has an ample thickness, a proposal to delete galvanizing of the inner bottom was approved by the Bureau to save $5,500.

REARRANGEMENT OF SPACES

This study of the LPD included several proposals to rearrange the internal spaces aboard the ship. Two of the most interesting projects involved the aviation gasoline tanks and the ladies retiring rooms.

Elimination of one of the two cofferdams aft of the aviation gasoline tank was proposed. These cof-

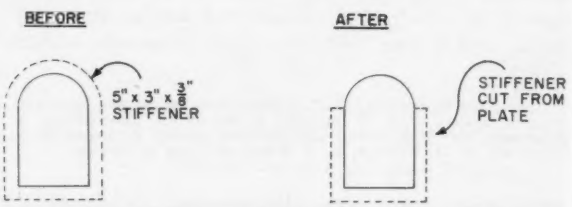


Figure 3. This shows the curved top of the shaft tunnels before and after the elimination of the angle stiffeners.

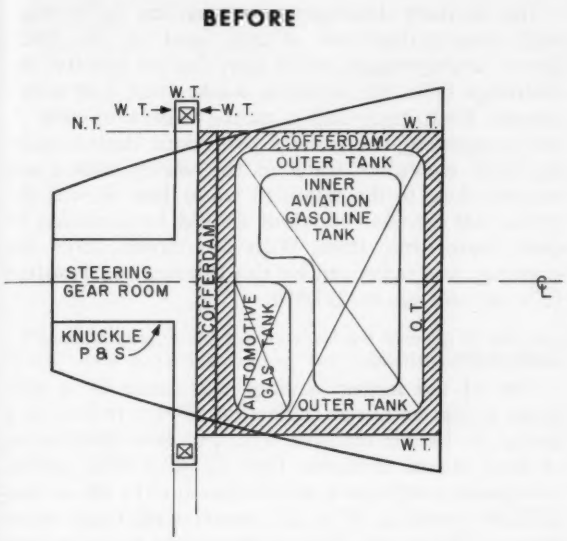


Figure 4. Showing the arrangement of the Aviation Gasoline tanks on the LPD as originally designed.

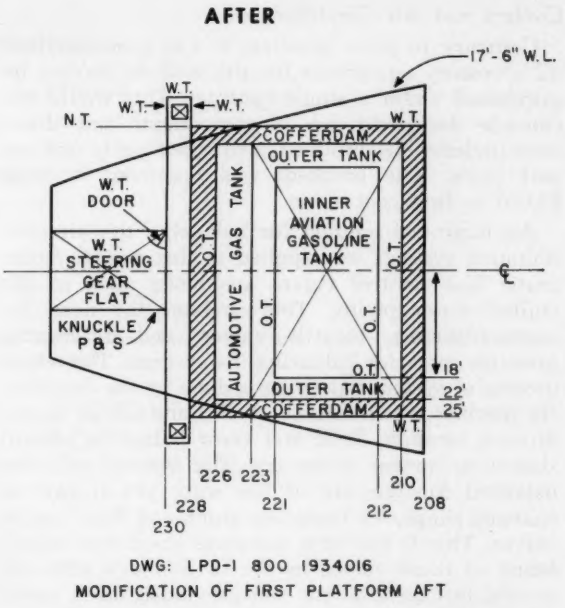


Figure 5. Showing the arrangement of the Aviation Gasoline tanks on the LPD after the elimination of one cofferdam bulkhead.

ferdams are filled with inert gas and enclose the top and four sides of the tank. (Figure 4) If only a single space was provided aft of the tank, the machinery in the steering gear room would have to be made explosion-proof. However, the existing athwartship passage could readily be made to act as a second cofferdam. This arrangement (Figure 5) was approved by the Bureau and actually saved $5,750.

Three ladies retiring rooms were shown on the contract drawings and required by the specifications. It was estimated that eliminating the furnishings in these three spaces would save about $9,000. The Bureau approved the elimination of one ladies retiring room. The two remaining spaces were relocated and furnished austerely for use when the ship entertained visitors. This action resulted in a saving of at least $3,000.

COMMERCIAL PRODUCTS USED

In several cases the use of commercial marine structure and fittings was proposed. The proposal was made to use commercial marine joiner doors with commercial marine hardware to save $4,700. This project was approved by the Bureau and Standard Navy type doors were not required.

Navy standard shipboard furniture made of aluminum was originally specified. It was found that $69,000 could be saved by using commercial marine furniture made of steel. The Bureau approved this change when it became known that the weight increase was within acceptable limits.

Could commercial marine watertight doors, hatches, scuttles and manhole covers (quarter inch medium steel) be used in lieu of Navy design? Originally the savings were estimated at $29,500. This project was partially approved by the Bureau for 84 W. T. doors and 26 W. T. hatches. Actual savings will be $8,078.

CHANGES IN DISTILLING PLANT AND CONDENSERS

The Navy type distilling plant is normally furnished with an economy number of 1.8 (The economy number is defined as the ratio of the pounds of distillate to the pounds of steam used). It was suggested that a commercially specified distilling plant with an economy number of 1.2 be used. The Bureau approved the determination of the most practical distilling plant economy ratio by the shipyard, based on the ship's heat balance and the design distiller capacity. This change resulted in a savings of $39,400.

It was further suggested that the two main condensers and the two main air ejectors be fabricated to commercial standards. A Navy specification required condenser heads of 90-10 copper-nickel. Commercial installations have steel heads which are neoprene lined. The original proposal was modified to include not only the main condenser but also the auxiliary condensers. It was approved by the Bureau and resulted in an estimated savings of $15,000.

This same approach was applied to the deaerating feed water heaters. A change from monel shell to commercial construction with steel shells was approved by the Bureau to save $44,000.

Coolers and Air Conditioning

Contrary to prior practice, it was proposed that all accessory equipment for the walk-in coolers be purchased under a single contract. This would encourage standardization of components and eliminate undesirable duplication of spare parts and repair parts. The proposal was approved to save $1,000 in first cost alone.

An improved method for balancing the air conditioning systems was applied to this design. Automatic flow control valves are being used in the chilled water piping. This obviates the need for venturi meters, throttle valves, and differential pressure gages for balancing the systems. The whole process of system balancing is done by the designer. He specifies which size (both IPS and GPM) to use in each location. Trial and error balancing aboard ship is no longer necessary. The system will stay balanced for the life of the ship; yet it can be changed simply by replacing union-end flow control valves. This is the first complete shipboard installation of these valves in the U. S. Navy although several test installations had previously been made. Approval by the Bureau resulted in a saving of $3,141 in the cost of procuring and installing components for this system.

Boiler Uptake Expansion Joints

The redesign of boiler uptake expansion joints was first proposed by the Boston Naval Shipyard.* These joints had previously been bolted in place (Figure 6). The plug welded joint had been approved for use on several destroyers but it was too

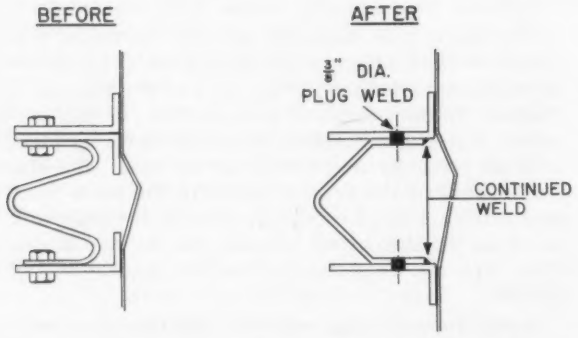


Figure 6. This shows the bolted type of Boiler Uptake Expansion Joint previously used and the plug welded joint which was approved for use on the LPD.

new to be included in the contract design of the LPD. New York was aware of this because of the Value Engineering Project Reporting System. As a result of this cross-fertilization, the local approval of this project saved $4,460.

*The Original Proposal for a simplified Boiler Uptake Expansion Joint was made under Boston Naval Shipyard Engineering Project 2040-111-49.

The sanitary drainage system on the LPD originally was a duplicate of that used on the LSD. Seven sewage tanks were provided to receive the discharge from the showers, washrooms, and water closets. Each tank had a motor driven ejector. It was suggested that gravity overboard drains could be used. However, some of the water closets are located close to the trimmed water line. It was decided that several eductors should be installed to clear these drain lines. With this modification, the proposal was approved by the Bureau and resulted in a net savings of $77,910.

Ballasting System

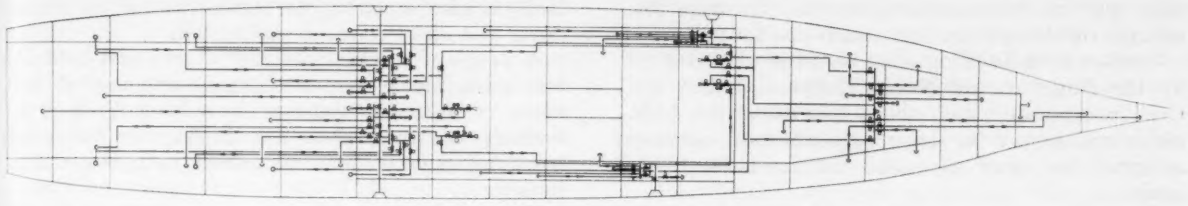
One of the largest savings was made on a proposal to use an air de-ballasting system in lieu of a pump for ballast transfer. This involves elimination of four steam turbines, four 12,500 GPM pumps, two steam condensers, accessories for the above and $750,000 worth of 4″ to 24″ copper-nickel salt water piping (Figure 7). It also eliminates the complete ballast stripping system as well as the suction and discharge sea chests. The above equipment is replaced by five electric motor driven blowers, associated accessories, 4″ to 14″ steel air piping and flooding valves in the ballast tanks. With gravity ballasting and air deballasting the system is less expensive, lighter weight, more easily controlled and faster. (Figure 8). This is a major design change which was made only after a thorough study of the design criteria for the system by Mr. R. E. Pfeiffer of the Bureau of Ships, Machinery Design Branch. The total savings resulting from this project are not yet known but they will surely exceed $100,000.

Acceptance of the air deballasting system obviated the savings which had been under study in connection with two other projects. The first of these was a study of the use of wrought iron piping instead of copper-nickel pipe and fittings for the ballasting system. This project had been rejected by the Bureau because the wrought iron piping did not have the required service life expectancy. A proposal to use electric motors in lieu of the turbine drive for the clean ballast system to save $32,400 had previously been set aside pending the acceptance of the air deballasting system.

One other project involving the ballast system was later approved locally at New York. After extensive study the use of capacitance type gages in lieu of pressure actuated depth gages in the ballast tanks was approved at New York. This change resulted in a saving of $25,685.

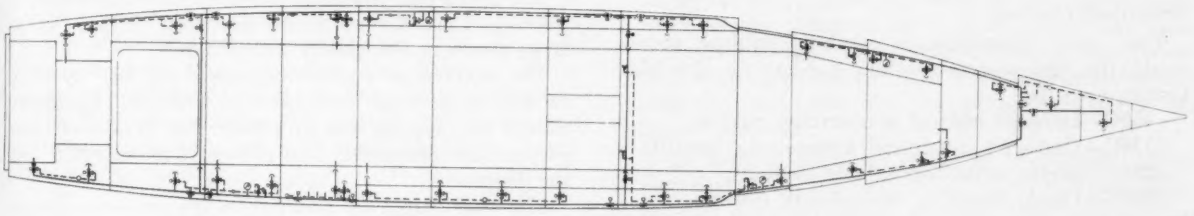
Interior Communication Systems

A dial telephone system provided service to all ship control stations, gunnery control stations, offices, living spaces, etc. This 100 line system would cost an estimated $150,000. The shipyard proposed using either a sound-powered system with "E"



BEFORE

Figure 7. This shows the number and location of the large copper-nickel pipes used in the inner bottom of the LPD for the water pump ballasting system. The ballast stripping system is not shown.



AFTER

Figure 8. This shows the number and location of steel pipes used in the upper levels of the LPD for the air deballasting system. (Note the cross connection of Port and Starboard pipe runs.)

calls or an "Administrative" type circuit (22 line automatic system).

A sound-powered, multiple-talking, selective-ringing telephone system was under test at the Portsmouth Naval Shipyard. However, cross-ringing troubles had not been solved. The 22 line "Administrative" circuit which would cost an estimated $25,000 would not provide enough stations. Therefore, the Bureau approved the use of a 50 line dial telephone system. It is estimated that this action will save $62,500.

The specifications required three voice tube systems in the ship control spaces. A study was made to determine if these could be eliminated by relying on the sound powered telephones. The proposal to delete two voice tube systems was approved by the Bureau to save $2,400.

The LPD has both a general announcing system (1MC) and a ships entertainment system (SE). It was suggested that the same electric cables and connection boxes could be used for both systems. The combination was approved by the Bureau and a saving of $7,500 per ship was made.

Could the course steering order system (Circuit 1LA) and its call bell system be eliminated? $1,500 could be saved if existing vocal communication systems could be used. The sound powered telephones can be used if chain-command and the relay method is desired to transmit course steering orders. The Bureau approved the change and the saving was made.

Elimination of the Type II interior communication switchboards in the machinery spaces was proposed. Standard ALB-1 power distribution panels and bulkhead mounted rotary type automatic bus transfer switches would do the job. The Bureau approved the change and thus saved at least $600.

The Constant Frequency Power Supply System, Circuit CF, provided a regulated 120 volt 60 cycle supply for the "Y" circuit. This circuit generates a distance factor which is used in the dead reckoning equipment. Since distance is run continuously, the regular ship service supply could be used. Temporary frequency fluctuations will average out. Elimination of Circuit CF and use of the regular ship service supply was approved by the Bureau for this ship. This project saved at least $3,000.

Isometric Wiring Diagrams

New York asked the Bureau to delete the requirements for preparing the isometric wiring diagram and elementary wiring diagram for certain systems. They proposed using a "System Diagram" to give an overall picture of the system. The System Diagram would be supplemented by wiring data in punch card form. This was approved by the Bureau for interior communication systems, electronic sys-

tems and the fire control system on this ship. The savings resulting from this action are $20,000.

Similar work is being done on other ship designs by the Puget Sound Naval Shipyard, Gibbs and Cox, Incorporated, and others. The use of this technique will save even larger amounts as it becomes accepted for other electrical and mechanical systems.

Its basic merit lies in having a machine make tabulations in the proper form for:

(a) procuring materials
(b) planning and preparing job orders
(c) inspection
(d) repair and
(e) conversion work when necessary

Combined Cabling

Two other proposals to combine cabling were made, the first was to combine cabling for the following circuits:

4MC—Damage control announcing circuits
21MC—Captain's command announcing circuits
22MC—Radio room announcing system
39MC—Cargo handling announcing system

This was approved by the Bureau and saved $10,900.

The second proposal was to combine cabling and connection boxes for the following circuits:

Circuit "HD-HE"—Wind direction and speed indication system
Circuit "K"—Propeller revolution indicator system
Circuit "M"—Propeller order system
Circuit "TL"—Dead Reckoning system
Circuit "MB"—Engine order system
Circuit "Y"—Underwater log
Circuit "LC"—Gyro compass

Estimated savings $2,300. Partially approved. Circuits "HD-HE," "K," "M," and "TL" approved for combining. Circuits "MB," "Y," and "LC" not approved because the Bureau did not want to combine vital circuits with non-vital circuits. Actual savings were $1,600.

Some Projects Still Under Study

We would like to include briefly some of the projects which are still being studied at the time of this writing for application on this and future ships. These include the possible use of commercial instruction books, plans and tests. Each boiler on this ship is required to have an auxiliary water level control from the general feed-water system. The proposal to eliminate this feature is being held in abeyance until bids and proposals have been received from the manufacturers. This project is pending locally with estimated savings of $6,000.

The use of high pressure, high velocity, conduit type ventilation system was proposed. This will require a substantial amount of development work especially for the fittings such as terminals. New York is also studying the extensive use of round ducts in a more conventional system.

A proposal to eliminate the motors and controllers used for electro-mechanical dogging of the lower ramp is still under study at New York. Preliminary estimates show that $3,000 may be saved by using only mechanical means to perform this function.

The well deck on this ship is sheathed with wood planking. This requires a substantial amount of lumber and careful fitting. Several proposals of alternative ways to provide this protection are under study.

Some Projects Not Approved

Not all of the proposals made by the Value Engineering Task Group were accepted. Three very large projects are briefly noted here:

The electronic countermeasures (ECM) system on this ship costs an estimated $450,000. Elimination of this system was proposed. The details of this project are classified. The project was rejected by the Bureau.

The short range air navigation system costs about $150,000 for the LPD. It is suggested that this system might be eliminated. The details of this project are classified. After this proposal was rejected by the Bureau, it was found that an additional $17,000 would be required to extend the deck-house for this equipment.

It was proposed that the Mark 63 Gun Fire Control System be used instead of the Mark 56 Gun Fire Control System. The savings were estimated at $100,000. The details of this project are also classified. It was rejected by the Bureau and the Ships Characteristics Board.

All of the rejected projects were not of such large scope. For example, the LPD has a Mark 56 Gun Fire Control System. It was proposed that the structure and components for this system be fabricated in the shop. Then the unit could be installed as a "Package" instead of building it in place aboard the ship. It was estimated that this might save $5,000. Further study of the unit and its location showed that no savings would be made so the project was rejected locally.

Sixteen Projects Canceled

Actually, quite a number of projects were canceled locally when it was found that no savings could be made. The largest project in this category was a proposal to use commercial electric motors and controllers. It was originally estimated that this change would save $77,000. After a very thorough study it was concluded that using modified commercial components would not result in any savings so the project was canceled.

Similar results were found upon investigating proposals to use commercial padlocks, to use commercial marine pantry and galley equipment, and

after a review of the requirements for workshops and tools.

Another project which proved to be a false start concerned casting propellers of nickel-aluminum-bronze instead of manganese-bronze. Further studies showed that the proposed material was more expensive and used only when ice operations or beaching requirements exist. This project was canceled locally and no savings were made.

MORE WORK BEING DONE

As was mentioned before, the above list does not purport to include *all* of the cost reduction work done on the LPD. It is merely a brief summary of some of the items studied by the Value Engineering Task Group.* The development of 75 projects in such a short time is highly creditable. Of course, many areas of potential savings had to be set aside because of the time limitation. New York is continuing to study and follow up these and other projects. Even disregarding this activity, the actual cost savings made as a result of the Task Group study are impressive.

Evaluation of Results

The cost of making the basic Task Force Study of the LPD-1 was less than $30,000. The total amount of money spent on Value Engineering this ship is less than $50,000. The 75 projects studied by the task group have resulted in savings estimated at over $663,000 on LPD-1. When the regular Value Engineering work done since the dissolution of the task group is added to this, the estimated savings are about $770,000.

This remarkable result must be attributed to the perseverance of the New York Design Division, excellent support from top management in the yard, and an outstandingly receptive attitude by Bureau personnel. It is even more impressive in view of the fact that these projects will result in 100 per cent reduced cost change orders. This fact ensures that the reported savings on the approved projects have all been conservatively estimated.

It will be noted that many of the projects which were referred to the Bureau could have been resolved locally. In some cases this reflects a post-audit rather than a pre-audit by the Bureau. The naval shipyards and local Supervisors of Shipbuilding have rather broad authority to issue field change orders for Value Engineering Projects.*

Several projects in this study affected matters under the jurisdiction of the Ship Characteristics Board. This was the first case in which such fundamental functions were reviewed by Value Engineers at the shipyard level. It is a fact that these projects involved very large dollar savings potential. Although none of them were approved for this ship they did clear the lines of communication for future projects.

Another interesting aspect of this study is the fact that 12 of the projects involved a Value Engineering approach to the function of a system. This is in contrast with the usual project where the scope is confined to a component. While the study of systems is a recent development in Value Engineering, it is a large step forward on the road to truly value engineered ships, containing value engineered systems, made up of value engineered components.

But, the true measure of the success of this work can be made by stating two facts. First, the New York Naval Shipyard has been assigned the construction of LPD-2 and LPD-3 to follow LPD-1. Secondly, a similar task group has been formed to study the Fleet Rehabilitation and Modernization (FRAM) conversions of four destroyers by New York Naval Shipyard.

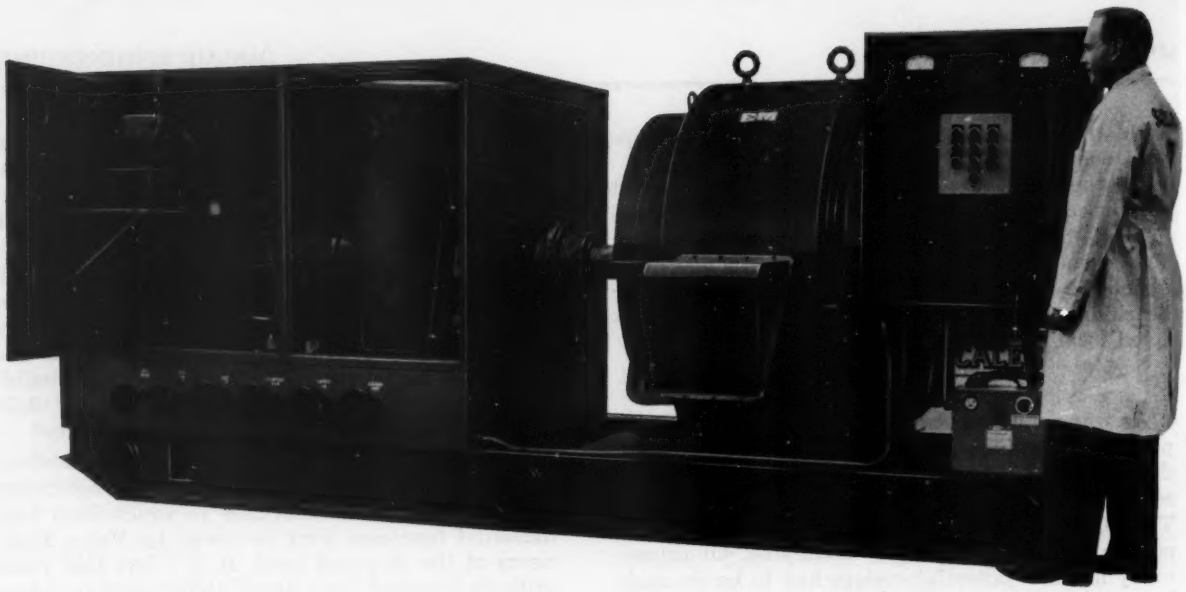
*Those readers who would like a complete report of all of the projects covered by the Task Group should address their requests to the authors.

*The Bureau of Ships policy on issuance of field change orders is covered in Bureau of Ships Instruction 4760.12B.

GIBBS & COX, INC.

NAVAL ARCHITECTS AND MARINE ENGINEERS

NEW YORK



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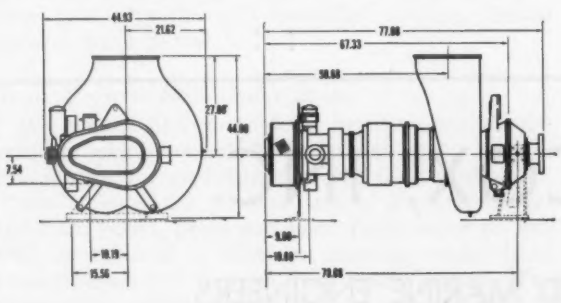

to a minimum. Installation is extremely simple. The engine is about 1/10th as heavy as diesel units of similar horsepower and occupies only 51 cu ft. No elaborate foundation or flooring base is required because the gas turbine is practically vibration-free.

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"ALL HANDS"

SAILING ON A BUBBLE OF AIR

ACKNOWLEDGMENT

The following article by Erwin A. Sharp, JOC, USN is reprinted from the December 1960 edition of "All Hands."

You might call it a helicopter without a tail, but it doesn't fly high enough. On second thought, you might call it a car without wheels. No, a car can't travel over water and this machine can cross water, mud, snow, or ice just as easily as dry land.

To be quite objective, it's more of a half-breed—half helicopter and half automobile with the extra qualities of a boat thrown in. Although these vehicles are generally known as Ground Effect Machines (GEM), most officials in the Bureau of Ships describe any GEM which operates over water as a hydroskimmer.

The hydroskimmer rides on a bubble of air. In its very simplest application, think of an upside-down wash tub with a powerful fan mounted down through the middle. Now, when you turn on this fan, the tub will rise off the ground. Maybe not evenly or maybe not on all sides, but it will rise up because of the effect of the air being forced into the cavity with no place to escape.

Even out this air pressure, or in other words, let the same amount of air pressure escape on all bottom edges at the same time, and the tub will rise free of the surface—provided you have enough power. Apply more power and your tub will fly higher. Get a larger tub and your machine will become more efficient. So mount a fan inside a tub and you'll have yourself a hydroskimmer.

Although still very much in the research stage, GEMs are believed by Navy experts to have a great potential, especially for a breakthrough in speed and for amphibious operations. They could carry troops and supplies from the ships to well beyond the shoreline. Larger ones could one day cross the ocean and deposit supplies on the beach.

Antisubmarine warfare may be another field where hydroskimmers will prove valuable. An ASW craft of this type could sit quietly on the surface until a contact is made, and then fly in for the kill at speeds of 80-120 knots. It could operate for longer periods than a helicopter because it would ride on the surface for certain periods, yet speed to the area of the contact faster than a ship. This yet-to-be tested method of ASW operation is called the Grasshopper Technique. It will probably first be used by the hydrofoil patrol craft currently under construction.

Hydroskimmers haven't quite acquired their sea legs yet. One expert has commented that they are in the same stage of development now that airplanes

were in 1909. In fact, the most ideal shape and propulsion system has not yet been determined. Currently it appears that a rectangular or almost round one is the most desirable.

One of the most successful skimmers yet tested, the *Hovercraft*, was oval-shaped. It was built in England and has made a successful English Channel crossing at speeds of 30 knots. (It is capable of 50 to 60 knots as currently modified.) This crossing proved so successful that a British company has announced plans to build a 100-ton vehicle to be used as a channel ferry.

Ground Effect Machines have caught the fancy of men in almost every field of transportation. A Bureau of Ships spokesman said that there is one already offered by a civilian company.

They are not the answer to every transportation problem, by any means. Right now, for example, the Navy is not even sure what type is the best suited for its purpose.

Engineers at the David Taylor Model Basin, where much of the Navy's testing is done, say that hydroskimmers can be divided into several basic types. Which one is best, and which one, if any, will finally become a Navy craft, is not yet known. In the meantime, each of the following types is being tested and considered.

Plenum chamber

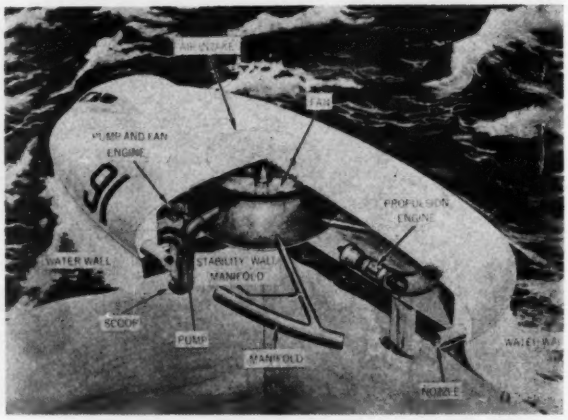
This is as close to the simple wash tub hydroskimmer as you will get. Air is forced down from the top and allowed to escape around the edges. As explained earlier, this lifts the machine free of the ground.

Air curtain

For this type machine, it will be necessary to add some more parts to your wash tub. First, put air jets pointing down and inward around the bottom edges. Next, divide the bottom of your tub into sections, let's say quarters, with open air ducts between sections. Here's how to make your machine work. First, force air down through the ducts between sections. This will form a high pressure air cushion on which your craft can ride. The air jets will hold the bubble under the skimmer. If your tub is rectangular you could add side walls (or skegs) and only have the air curtain forward and aft. This particular type, however, would probably be limited to use on water. Forward motion for this machine, like most others of this type, can be furnished by changing the angle of the air jets, or by separate propellers, or both.

Water curtain

About the only extra equipment you'll need this time, besides that which you already have for your air curtain machine, is a water pump. That's in addition to a lake or some other body of water on which to operate it. You still need the air bubble



THE WATER WORKS—Sectional view shows how hydroskimmer functions.

under the vehicle. The big difference with this one however, is that the jets around the outside must eject water, not air. Of course to get this water, you must have a scoop in the water and a water pump. Although the water will more efficiently keep the air under the vehicle, there is some doubt whether the extra efficiency is worth the extra weight and equipment that must be installed. Propulsion for this type machine would probably be by a propeller in the water.

Ram wing

Your wash tub has outlived its usefulness now. For this one you'll have to draw on your experience as a model airplane builder—it's nothing more than a flying wing. It's not a new concept. A Finnish engineer, T. J. Kaario, suggested it way back in the early thirties. This type machine looks like a wing of an airplane and even uses a similiar principle of flight. When this particular hydroskimmer increases speed, less power is needed to keep it aloft because of the ram effect of air entering the front of the machine.

The Navy is not sure which of these configurations is the best. Maybe one will prove better for certain applications and another for a different job. Right now it doesn't look as though you'll serve aboard one during this hitch.

Before larger skimmers can be built the Navy wants more performance data. Navy engineers have been testing small scale models at the David Taylor Model Basin for several years now. Besides that, certain civilian companies are developing experimental craft for the Navy.

Before the end of the year, the Bureau of Ships plans to have at least four hydroskimmers under test. These craft will be about 20 feet long and both air and water walls will be used.

The Navy has already tested the *Hydrostreak*,

which has water walls fore and aft and skegs on the sides. This type of vehicle is limited to operations over water.

Another water wall vehicle has also been delivered to the Navy. It has water on all sides, however, not just fore and aft. This vehicle will be capable of 15 knots or more.

An aircraft company is also producing a hydroskimmer for BuShips. It has air fore and aft with side skegs. Vehicles of this type have a much higher speed potential than the water wall types.

A fourth craft is being concurrently tested by the bureaus of Weapons and Ships. It will be a diamond-shaped, full-peripheral air machine.

Besides these vehicles which are undergoing Navy tests, Bureau of Ships officials are interested in several other air-supported craft. One such craft is being tested by the U.S. Marine Corps and several by the U.S. Army and Air Force. One successful hydroskimmer is the already-mentioned *Hovercraft.*

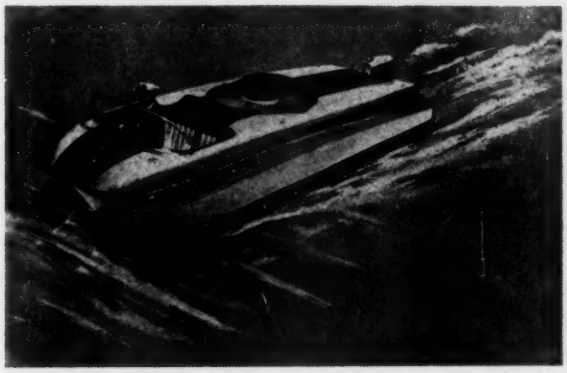
Another craft which may provide useful data not only has side skegs, but also has flaps forward and aft which move up or down as they are hit by waves. This is a fairly new field of research, and not too much apparently is known of it yet. A hybrid, it does not strictly qualify as a hydroskimmer —its inventor calls it a "lubricated craft."

Hydroskimmers have a place in the future U.S. Navy. Current development plans in the Bureau of Ships call for a craft about 40 feet in diameter which would be a large scale model of an ocean-going craft. In a later building program it is expected that an experimental type will be built of a size large enough to demonstrate ASW capacity in the open ocean.

Although the Navy knows the skimmer theory works, it's hard to determine just how larger ones will operate. Engineers believe that as they increase in size, they will also increase in efficiency. This leaves one to speculate that future aircraft carriers or large ocean-going transports may be hydroskimmers. Although laymen may question whether cargo can be stored in this type craft, the experts maintain that when they reach operational size, there will be room for more cargo than the craft can lift.

It is hoped that operators of small amphibious type hydroskimmers will be able to handle their craft with little more training than they now need to operate present day landing craft. The vehicles will probably be harder to maintain and repair than today's amphibious type craft, but less difficult to repair than an airplane.

Air-supported vehicles are not perfect. For one thing, they are noisy. And possibly the biggest problem is the high velocity downwash. In other words they kick up a lot of dust on land and a heavy mist at sea, This downwash problem decreases, however, when the vehicles operates about



NEW MODEL—Sketch shows hydroskimmer to be delivered to the Navy.

30 mph or faster—at which speeds they outrun the fog or dust.

The mist effect will make it almost impossible to load these craft while they hover over water. It will be necessary either to land them on the water or hover them over a hard surface. These are matters that will be further explored after hydroskimmers become operational.

Probably one of the most difficult maneuvers to be learned by a hydroskimmer operator (or driver or pilot, whichever he will be called) will be to turn or to stop. Its stopping characteristics will be much like an airplane. You don't stop an airplane in the air, and hydroskimmers will be much the same. At present, it appears that the only way to stop them is to reverse propulsion, hover, and then set them down.

When it comes to turning corners, there is no great problem except that the operator must use a greater area in which to turn (mechanically, the vehicle will be turned by changing the angle of the air jets). Besides that, he'll have to make up his mind to turn before he gets close to an obstruction—there can be no last minute decisions.

Hydroskimmers are potentially faster than any other type Navy ship now in existence or even in the dream stage. Peripheral air seems especially suited to high speeds because it will be hampered only by wind resistance. Water wall vehicles or vehicles with side skegs will have a certain amount of drag in the water and will therefore be unable to obtain the high speeds that will be possible with the peripheral air machines.

Another area of speculation regarding hydroskimmers is their seaworthiness. Maybe this will determine the type the Navy will decide to use. The vehicles with side skegs may be more seaworthy, say, than a peripheral air machine. Yet the one with skegs would be limited to lower speeds because of the water drag. They might also be restricted to the water.

The reaction of GEMs in at-sea conditions is an-

other question mark in their development. About the only concrete proof of their ability was shown last year when the British *Hovercraft* crossed the English Channel. That craft flew only about a foot above the surface, yet it was easily maneuvered through four foot swells at speeds up to 30 knots. Ocean-going hydroskimmers are expected to fly about 10 feet or more above the surface.

But what happens if you lose power while flying at say, 50 knots? Will it glide to a stop or will it crash immediately? And if it crashes, will the lightly constructed machine take the beating? These are in an area of speculation and until more research is done and eventually larger hydroskimmers are built, they will remain in that area. The Navy will find the answers, but it may take a while.

AIR CONTROLS THE WAVES

At the entrance to one of the docks at Dover Harbor air is being used to calm the waves instead of the conventional concrete breakwater or steel lockgates. This new method has been developed by Pneumatic Breakwaters and wave reductions of 80 per cent are being daily achieved.

Large bubbles, approximately the size of a football, are emitted from what is to all intents and purposes an air-lift pump located at the bases of a number of polythene tubes on the sea bed. At a frequency of one every four seconds bubbles pass up the tube and through two large ports cut in the wall. This induces water to travel up the tube also. With the break-up of the large bubble into a large number of small bubbles, the water is kept moving upwards to the surface. Thus, incoming waves meet this moving wall of water and a large part of the wave mass is turned back upon itself.

The complete installation consists of a number of pumps, or 'bubble-guns,' complete with long polythene tubes anchored on small concrete blocks and flexibly connected to each other. The air supply is provided by a conventional air compressor. The output per gun can be varied up to a maximum of thirty gallons per second. This takes about $\frac{1}{2}$ h.p.

Where vessels are liable to pass over the units an auxiliary flotation gear can be incorporated. When in use the tubes are vertical in the water but when not required they lie horizontally on the sea bed. In this way they effectively work as a lockgate. The advantages of this system are that there are no moving parts, ease of installation (it can be installed from a rowing boat); any number of units can be operated in parallel from an appropriate compressor; and the units can be picked up and moved easily from one site to another.

This 'air breakwater' should prove most useful in out-of-the-way locations where either the cost or the temporary requirements prohibit the building of a costly stone or concrete breakwater and during construction of drilling rigs, bridges, dykes or any other activities calling for calm water.

—MACHINE AGE

K. KAFALI

PROPELLER CHARACTERISTICS WITH DIFFERENT LOCATIONS OF THE RUDDERS IN THE PROPELLER RACE OF TWIN RUDDERS—TWIN SCREWS SHIPS

THE AUTHOR

studied naval architecture at the Department of Naval Architecture Mechanical Engineering Faculty of the Technical University of Istanbul. Graduated in 1948 and has been an Assistant Professor at the Department of Naval Architecture, Technical University of Istanbul since 1953. His work is connected generally with problems of theoretical naval architecture. The research work on which this paper is based was performed by Professor Kafali while he was a guest at the Massachusetts Institute of Technology under an appointment sponsored by The I.C.A. and administered by The National Academy of Sciences.

SUMMARY

The research deals mainly with experiments of a one rudder-one screw combination which is supposed to represent the condition of the twin rudders-twin screws type, This study includes only the case of rudder which was placed inboard of propeller centerline and located in the propeller race. Different locations of rudders have been the subject of investigations to study the optimum position relative to the propeller.

INTRODUCTION

IT IS CURRENT practice to place twin rudders on twin screw ships which require, as a part of their prime characteristics, a high degree of maneuverability. These rudders are generally located a slight distance inboard of the propeller centerline to avoid as much as possible operating the rudders in the hub vortex of the propellers. This expedient may minimize the loss of lift and erosion of rudders.

Published research on the characteristics both of propellers and rudders of a twin rudders—twin screws combination and on the location of rudders which are offset from the centerline of propellers is very scarce [1], [2]. These two reports deal also only with rudder characteristics.

Therefore, it would be interesting to test for the optimum location of rudders which might provide an improved or rather better performance of the propellers from the propulsive point of view.

NOMENCLATURE

$\frac{a}{R}$ = gap ratio

$\frac{b}{D}$ = distance ratio

a = gap shown in Figure 1
b = distance shown in Figure 1
D = diameter of propeller
R = radius of propeller
M.W.R. = mean width ratio
B.T.F. = blade thickness fraction

K_T = thrust coefficient $\frac{T}{\zeta n^2 D^4}$

K_Q = torque coefficient $\frac{Q}{\zeta n^2 D^5}$

T = thrust of propeller
Q = torque of propeller
n = revolution per second of propeller

e_p = efficiency of propeller, $\frac{J}{2\pi} \cdot \frac{K_T}{K_Q}$

J = advanced coefficient $\frac{v}{nD}$

v = speed of propeller
ζ = density of water

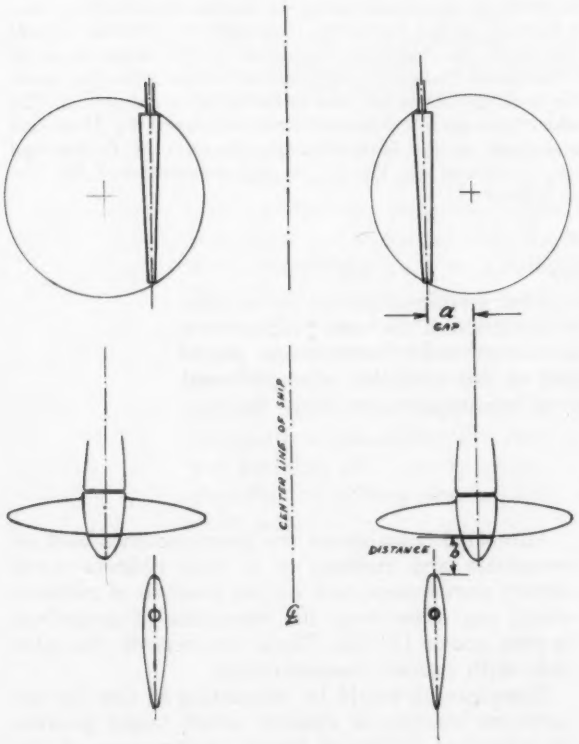


Figure 1

Typical examples of this type of installation can be seen in [3], [4].

DESCRIPTION OF EXPERIMENTS

As mentioned before, this research has been carried out to find an effective position for rudders. For this purpose, the M. I. T. Cavitation Tunnel, a description of which is given in [5], has been used.

Through the upper opening of the tunnel, the rudder was placed on bar frames in such a way that the gap and distance between rudder and propeller could be altered by moving the rudder transversely and longitudinally on the frames.

The rudder had been settled to the left side of a right-hand propeller centerline, the description of which is given in Figure 1 and Table I. This propeller is supposed to correspond to starboard wing propeller of a twin screws-twin rudders ship. Three different distances from the propeller hub edge and four different gaps from the propeller centerline were selected.

The dimensions of the cast bronze rudder and aluminum propeller are given in Table I.

TABLE I

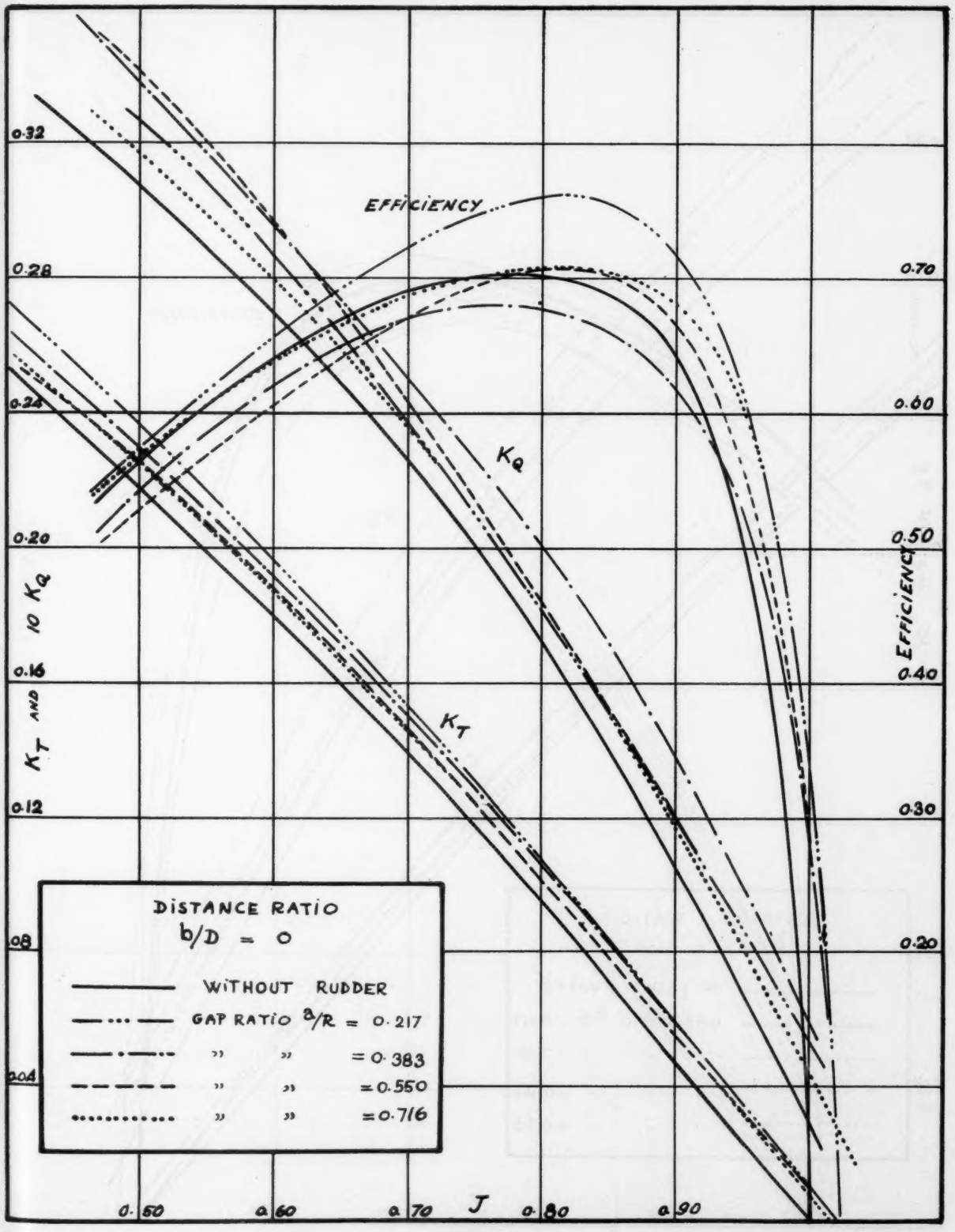
Rudder		
Aspect ratio	1.67	
Area	60	square inches
Location of Maximum Thickness	2	inches from leading edge
Maximum Thickness of Upper Section	0.76	inches
Maximum Thickness of Lower Section	0.70	inches
Stock Center	2	inches from leading edge
Sections		symmetrical airfoil
Propeller		
Diameter	12	inches
Pitch	12	inches
M.W.R.	0.248	
Sections		airfoil
B.T.F.	0.05	
Number of Blades	4	
Rake		none

For each distance of rudder from propeller hub edge (Figure 1), four different gaps selected were 1.30, 2.30, 3.30 and 4.30 inches from the propeller centerline. The three distances were 0, 1 and 2 inches.

During the tests water level of the tunnel was kept nearly constant, and it was maintained about 30 inches from the shaft line of the cavitation tunnel.

RESULTS AND OPTIMAL LOCATION OF RUDDERS

Results of thrust coefficient K_T, torque coefficient K_Q and efficiency based on the advance coefficient J of individual experiments of three different distance ratios and for four different gap ratios are given in Figures 2, 3 and 4.


EFFICIENCY
K_Q
K_T
10 K_Q
K_T AND
EFFICIENCY
0.32
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0.08
0.04
0.70
0.60
0.50
0.40
0.30
0.20
DISTANCE RATIO
b/D = 0
WITHOUT RUDDER
GAP RATIO a/R = 0.217
" " = 0.383
" " = 0.550
" " = 0.716
0.50
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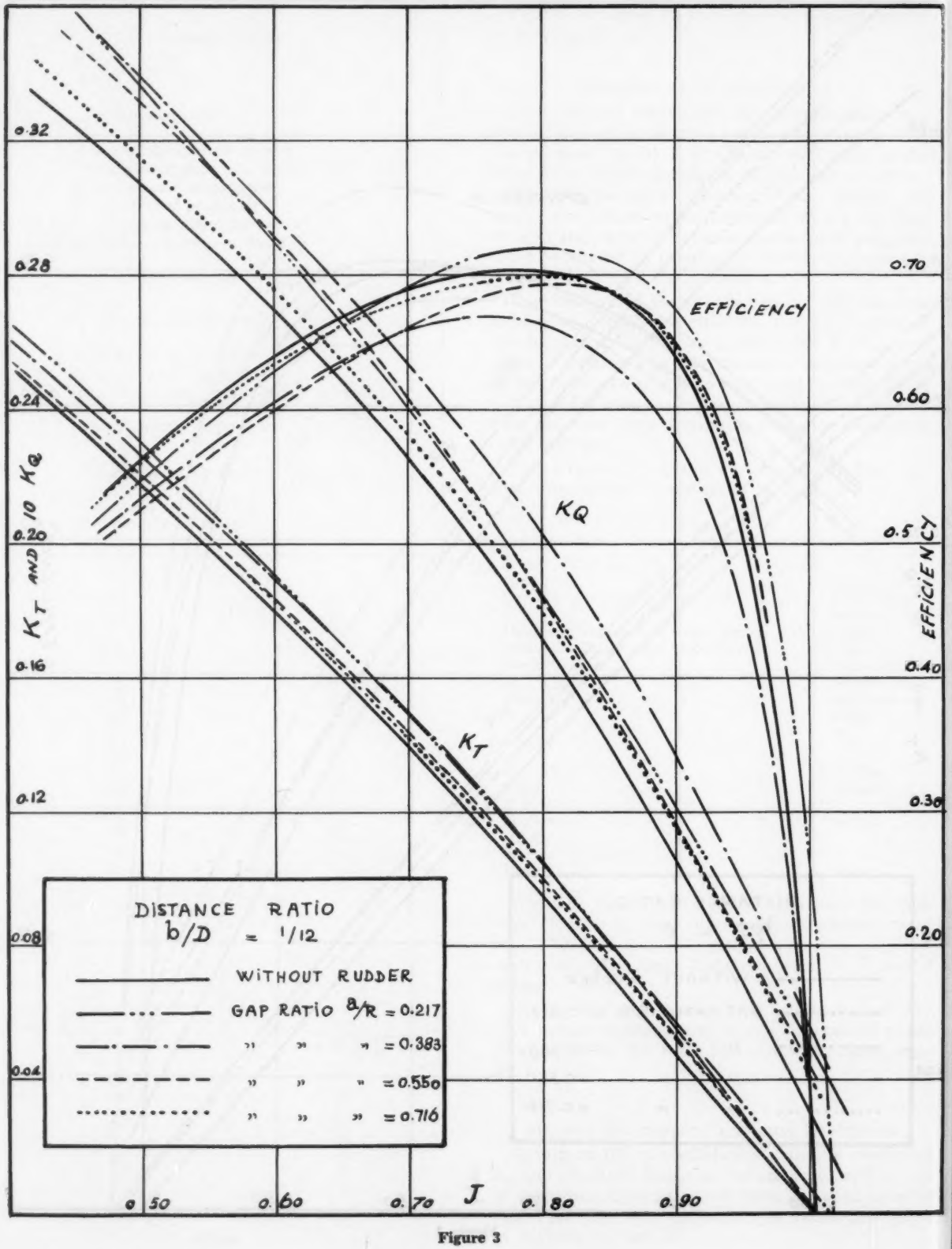
0.90
J

Figure 2


0.32
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K_T AND 10 K_Q
EFFICIENCY
0.70
0.60
0.5
0.40
0.30
0.20
K_Q
K_T
DISTANCE RATIO
b/D = 1/12
WITHOUT RUDDER
GAP RATIO a/R = 0.217
" " " = 0.383
" " " = 0.550
" " " = 0.716
0.50
0.60
0.70
J
0.80
0.90

Figure 3

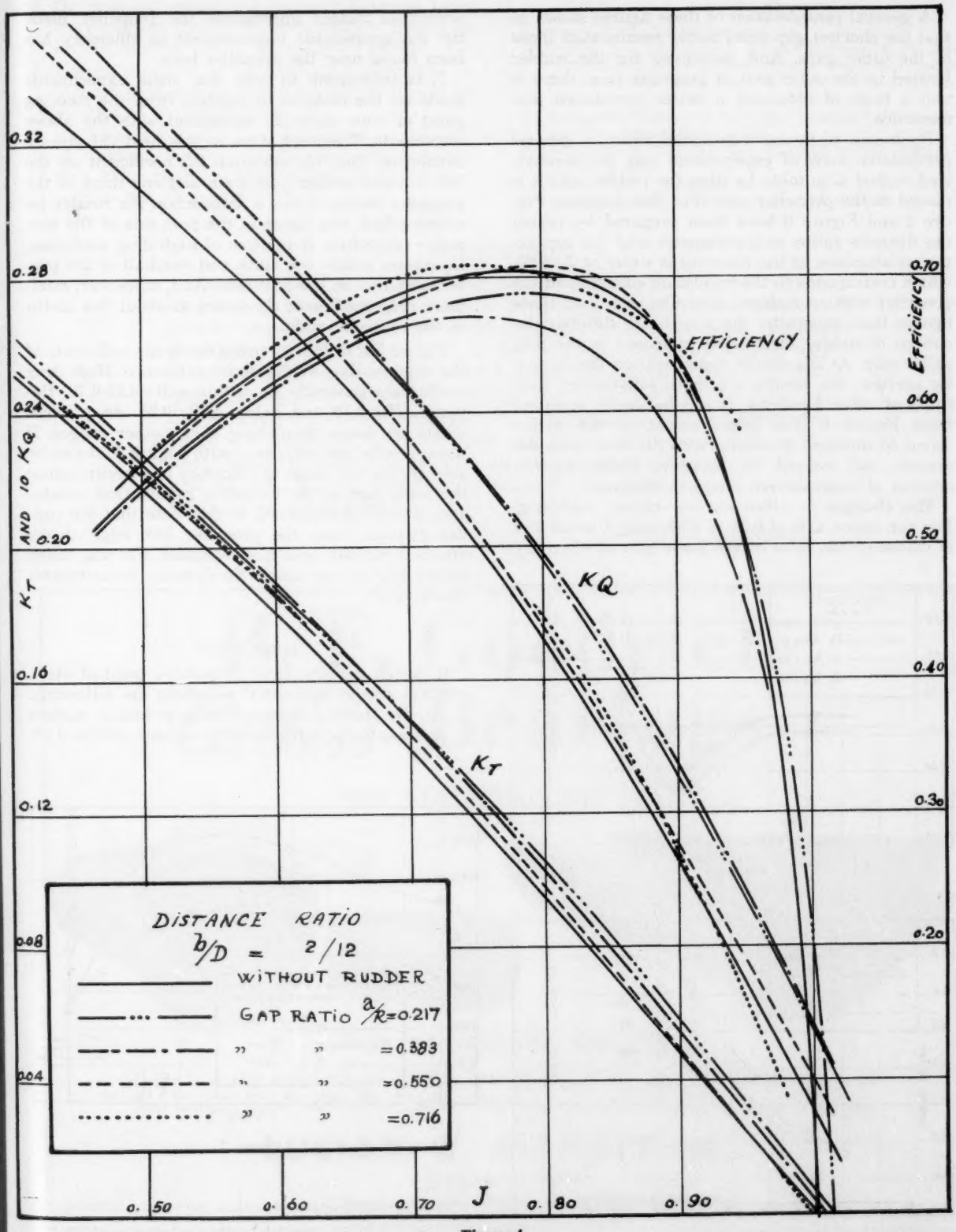
0.32
0.28
0.24
0.20
0.16
0.12
0.08
0.04
10 KQ AND KT
EFFICIENCY
0.70
0.60
0.50
0.40
0.30
0.20
KQ
KT
0.50
0.60
0.70
0.80
0.90
J
DISTANCE RATIO
b/D = 2/12
WITHOUT RUDDER
GAP RATIO a/R=0.217
" " =0.383
" " =0.550
" " =0.716

Figure 4

A general consideration of these figures shows us that the shortest gap gives better results than those of the other gaps. And, moreover, for the rudder located in the outer part of propeller race, there is still a hope of obtaining a better propulsive performance.

By means of figures mentioned above, a general perspective view of experiments may be summarized to find a suitable location for rudder which is placed in the propeller race. For this purpose, Figure 5 and Figure 6 have been prepared by taking the distance ratios as a parameter and the gap ratios as abscissae at the convenient value of J=0.80, which corresponds to the maximum efficiency of the propeller without rudders. It can be seen from these figures that, generally, the thrusts for different locations of rudder seem to be improved in the propeller race. At the closest distance from the propeller surface, the results are more satisfactory than those of other locations. It can be easily observed from Figure 6 that improvement of the thrust seems to increase gradually with distance ratio decreases, and toward the propeller blades tip the amount of improvement seems to diminish.

The changes in efficiency are rather confusing. For gap ratios a/R of 0.25 to 0.50, only a small loss in efficiency has been noted. Some gain of efficiency occurs as rudder approaches the propeller blade tip. An appreciable improvement in efficiency has been found near the propeller boss.

It is interesting to note that some experiments made on the location of rudders from the steering point of view show an agreement with the above statements. The work done in this field [2] gives a conclusion that, for optimum lift coefficient on the left or right rudder, one sixth and one third of the propeller radius shows a satisfaction for rudder location which was taken at the port side of the propeller centerline. A position of high drag coefficient C_D occurs within one sixth and one half of the propeller radius on the port side. And, moreover, minimum drag coefficient C_D occurs at about five sixths of the propeller radius.

Figure 7 is drawn by using the drag coefficients of the original data of the above reference. High drag coefficients generally lie within a/R=0.25-0.70. Beyond a/R=0.70 and below a/R=0.25, drag coefficients are lower than those of the other ranges. If these results are compared with Figure 5, it can be seen that a low range of efficiency also occurs about the same part of the propeller radius. One conclusion should be explained to this, note that the rudder distance from the propeller hub edge of the above work has been kept constant and was taken rather beyond our cases. No distance measurement was given.*

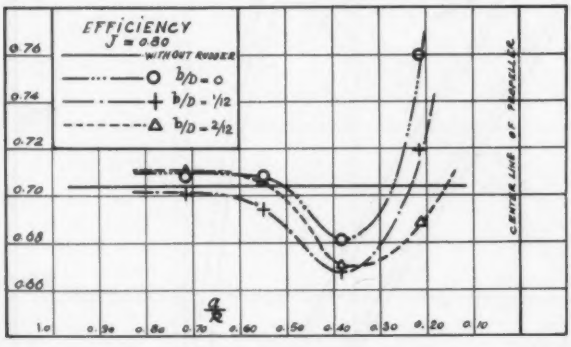

Figure 5

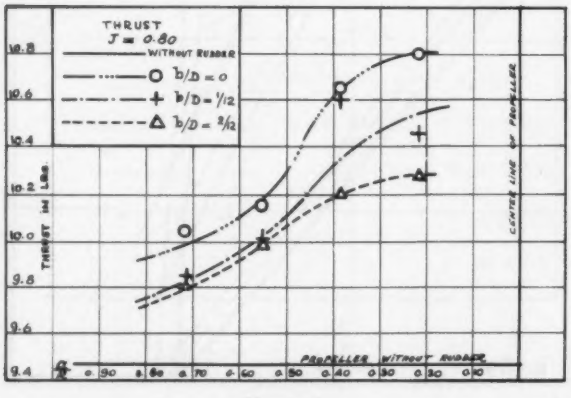

Figure 6

CONCLUSION

If design permits, from propulsive point of view, rudders should be located to satisfy the following:

1. At the shortest distance from propeller surface and gap ratio a/R should be chosen within 0.10-0.20.

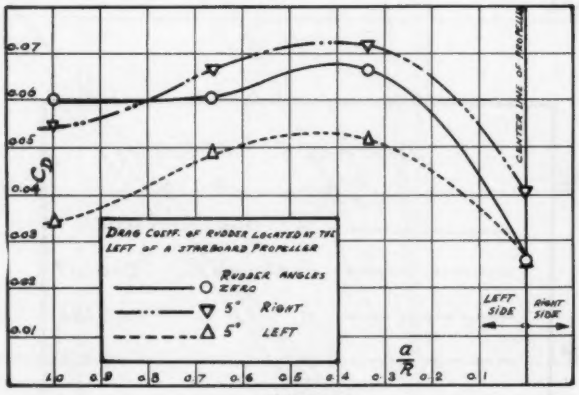

Figure 7

*In large turning angles of rudders, some design difficulty will arise for the cases of small distances and small gaps because of the possibility of the rudders touching the hub cone of the propellers.

2. Or, without considering unusual distances from the propeller, for any distance rudders should be located beyond 0.60 of the propeller radius.
3. For the condition of which thrust is desired to be highest, gaps and distances of rudders should be selected to the condition of (1).
4. By considering also the steering characteristics of rudders, the first conclusion seems satisfactory. This result has been confirmed by self-propulsion test of a model [1].

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[2] Downs, B. H.; Swayne, C. B.; and Henning, R. E., "Investigation of Rudder Characteristics with Variations of Rudder Position in a Propeller Race," M. I. T. Thesis, 1950.
[3] Lammeren, Troost and Koening, "Resistance, Propulsion and Steering of Ships," p. 338.
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[5] Lewis, F. M., "Propeller Testing Tunnel at the Massachusetts Institute of Technology, SNAME, 1939.

HYDROFOILS

Plans are being drawn by a Swiss concern for a hydrofoil craft 120 ft. long and 47-53 knot speed to carry 240 passengers on various Mediterranean runs. The largest boat of this type, 88 ft. long, carrying 110-140 passengers at 38 knots, began service this year between Naples and Capri-Ischia. Others are said to be running between Stavanger and Bergen, Norway, and between Stockholm and Mariehamn in the Baltic. A smaller boat, the ***Flying Fish***, carrying 60 passengers, built at Messina in 1956, was employed in Puerto Rico and has been brought over to the West Coast to make two round trips daily between Bellingham, Wash., and Victoria, B.C., a 50-mile run, in about 1½ hours, or half the time taken by the existing ferries.

—MARINE JOURNAL

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HISTORY OF NAVAL AVIATION

Fifty years ago a brand new infant emerged upon the naval scene and found only a few die-hard enthusiasts that would predict its survival. Now, just about everyone is agreed that the airplane is here to stay.

The Navy did not jump into this new field blindly. As early as 1898, Assistant Secretary of the Navy Theodore Roosevelt, impressed by Professor Samuel Pierpont Langley's success with flying models, had speculated upon the role of aircraft in war.

Then, in 1910, the Navy took its first hesitant step, appointing CAPT Washington Irving Chambers, USN, to answer correspondence on aviation and to keep himself informed of all activity in the field. After airplane builder Glenn Curtiss met CAPT Chambers in the autumn of 1910, Curtiss set out to convince the Navy of the practicability of aircraft. At his urging, a series of demonstrations was conducted with Curtiss airplanes landing aboard and taking off from specially built platforms on the Navy cruisers ***Birmingham*** and ***Pennsylvania.***

The Navy's first aviator, LT T. G. Ellyson, watched Curtiss land his hydroaeroplane alongside the ***Pennsylvania.*** Later, along with Naval Aviators 2 and 3, LT John Rodgers and John H. Towers, LT Ellyson set up a flight-training camp at Greenbury Point, near Annapolis, Md., after Navy Secretary George von L. Meyer decided to go ahead with a Naval Aviation program.

The red letter day came on 8 May 1911. It was on this day that the U.S. Navy purchased its first aircraft and set out to eventually prove that the airplane would change naval strategy.

The following year, in 1912, the Marine Corps became interested in aviation and Marines began reporting for flight training.

Early in 1914, the old Pensacola Navy Yard became the Naval Aeronautic Station. Here thousands of young men were destined to train as Naval Air Cadets.

The first carrier, USS ***Langley***, was converted from the collier ***Jupiter*** and commissioned on 22 March 1922. The following fall, the first carrier takeoffs and landings were made on its flight deck. The lessons learned here were incorporated in the ***Saratoga*** and ***Lexington*** which were being converted from battle cruiser hulls and destined for commissioning in 1927.

The first carriers designed from the keel up as such, ***Ranger***, ***Yorktown*** and ***Enterprise***, joined the Fleet in the 30's. By the beginning of World War II, the Navy had acquired a wealth of experience in operating aircraft at sea. The young naval aviators of the 20's, older and experienced, led younger ones to peak success in World War II aerial combat.

Another new era was born as new guided missiles became operational in 1954. Then, such significant advances as the steam catapult, angle-deck conversions, and mirror-landing system adapted World War II ***Essex***-class carriers to handle faster and heavier aircraft and increased safety and operational flexibility. These and other structural and technical refinements were embodied in the ***Forrestal***-class carriers and even further in the new ***Enterprise***, as nuclear power was adapted for this supercarrier's engine plant.

A relatively few years have seen the birth of jet propulsion, supersonic speed, guided missiles and other weapons of awesome destructive capability, and the extension of man into space. The Navy stands on this threshold to a new future confident that its air arm has and will hold its proper place as an integral, dynamic, and effective element of United States sea power.

—BUPERS NEWSLETTER

"SHIPBUILDING EQUIPMENT"

THE MODERN DIVER

ACKNOWLEDGMENT

This staff article appeared in the November 1960 edition of "Shipbuilding Equipment," from which it is reprinted.

THE SHIPBUILDER, owner or repairer requiring the services of a diver usually anticipates a greater amount of time being spent and a larger number of men employed to do a job, or obtain information, underwater than would be necessary for the same operation above the surface.

While the greater proportion of commercial diving is still carried on with equipment of a pattern designed at the beginning of the century a new, more mobile, diver is beginning to make his presence felt.

The conventional or standard diver often tends to have a conservative approach to problems and a preference for established methods, procedures or drills. The modern diver however tends to be more flexible in his approach to problems and generally has the ability to apply up-to-date scientific knowledge for their resolution.

The shipbuilder, owner or repairer, being actively concerned with the saving of time and money, should therefore be aware of the capabilities of the new type of diver.

THE DIVER AND HIS PERSONAL EQUIPMENT:

Essentially a diver is a man so trained and accustomed to the use of protective clothing and breathing apparatus that he is able to ignore this impedimenta and to carry out whatever work he is qualified to do with a facility equal to that of a workman ashore—the ability to dive is no virtue in itself.

Breathing equipment must be able to give as much clean, cool breathable gas as is required, without appreciable effort on the part of the diver, and to permit little more excess of CO_2 to accumulate than occurring in the atmosphere. Furthermore the gas supply must not be so complex an arrangement that it limits the diver's activities with heavy cylinders and cumbersome low pressure pipe line, any air supply line, in fact, should be able to double as the very necessary lifeline. Finally the diver should not depend entirely on the correct functioning of any mechanical valve for his air line supply although, up to the present, no apparatus is available which gives the diver an efficient emergency reserve.

To ensure the utmost mobility the modern diver will wear a watertight, lightweight suit of a very tough, proofed synthetic fiber over a foamed plastic suit which insulates him against the rapid heat loss which normally occurs in water.

The diver so dressed and wearing fins, to increase his ability to move easily, will be wearing little more impedimenta, nor weigh appreciably more, than a surface worker on a cold day. In this manner he will be just neutrally buoyant.

ADDITIONAL EQUIPMENT AND INSTRUMENTS

Where there is a stable platform available, as is normal in ship repair work, entirely self-contained gear, in which the whole gas supply is carried by the diver, will seldom be needed. With a diver who operates in this way the diving boat, if required, will invariably be of the inflatable type and carried in the same vehicle as the diver, his equipment and compressor. Inflated on site the boat will probably have an outboard engine clamped on to it after it has been dropped into the water from the dockside.

Communications are often vital and recorder/telephone equipment will be carried, this gives the diver clear communication with his attendant in the boat or, if he is working single-handed, allows him to record his survey observations.

The diver's work invariably begins with a survey to find out what has to be done and to assess the various means of doing it and, as visibility underwater in ports and docks is generally nil, he has to rely on his sense of touch. There is however a range of instruments available for indicating fine detail which would escape the sense of touch. Water is a particularly effective medium for the operation of ultrasonic apparatus which can be used to detect flaws such as the end of a fracture in a plate. It is also an excellent medium in which to handle radioactive materials and thus take radiographs of otherwise inaccessible parts of a structure.

Where visibility of an inch or more is available then closed circuit television or simple photography may be used. The former, with the camera handled by the diver to instructions given from the surface, gives an instantaneous picture on any number of screens but, for many jobs, may be too expensive. In this case photographs made on the Land principle can be used. These give a good positive print, fully developed, just one minute after releasing the shutter. Such photographs are useful adjuncts to a survey report.

The foregoing methods apply at this time. It has however been found possible to generate acoustic frequencies, through water, having the wavelength of visible light which will, if it can be focussed and manipulated, give fine definition. This control has apparently been reached by Russian scientists, in the laboratory, but it is not yet commercially applicable.

THE DIVER'S CAPABILITIES AND METHODS

Although often hampered by having to rely on touch rather than sight, a much keener sense, the diver has a greater potential than the surface worker. He does not have to support his own weight and, using properly designed tools which are also almost weightless, his ability to 'float' up and down the surface of a rudder or around the blades of a propeller, without the staging required by a drydock workman, or to swim the length of a ship's bottom, unobstructed by blocks, are valuable attributes.

Water pressure also is helpful, a blank placed over a 6 inch diameter aperture 10 feet below the surface is held in position by a pressure of approximately 140 pounds, which is not inconsiderable when transferred to a narrow strip of sealing material.

To date it has been impossible to make an underwater weld that would bear inspection or pass a Lloyd's surveyor. This is a principal and urgent problem which fortunately seems capable of early resolution by using a combination of heat insulating and induction welding techniques.

The use of shaped explosives for the cutting of metal sheets is advancing and will shortly be available as an economic method of trimming distorted or awkward plates, even in the close proximity of comparatively delicate fittings. The past difficulties of retaining the shape and flexibility of the charge, and of the lining material which actually does the cutting like a knife, within small tolerances, appear to have been overcome and the method is practical and fast.

The flame cutting of steel underwater is now a well developed technique used by most companies employed in diving. The two main methods employed use either oxy-hydrogen or oxy-arc. Of these the latter has the advantage of using only one gas while the necessary generator can also be used for welding.

With the increasing use of plastic coatings and anti-corrosion systems, time between dockings can be extended with intermediate dry-docking only occurring on occasions of major work such as the replacement of a tail shaft or withdrawal of a stabilizer fin. In this manner heavy expense and delays can be considerably reduced.

SHIP DESIGN AND EASE OF REPAIR

While it can readily be seen that modern materials and techniques can keep a ship, under normal conditions, out of the dry dock for a considerable period of time the possibility of a vessel being forced to dock for a comparatively minor purpose, because the possibility of certain repair and maintenance work being undertaken with the vessel afloat was never considered at the design stage, must be faced. For example, the renewal of stern gland packings while afloat appears a makeshift maneuver; however, if the design were such that the rope guard could be easily removed and a larger sealing gland fitted during the repacking then the operation would become a routine matter. Similarly, a set of blanks or sealing covers to fit the underwater apertures of a ship could readily be supplied by the builder, as part of the vessel's outfit, and would substantially reduce the difficulty of a repair to a skin fitting.

Obviously, to make the fullest use of a design which allows the outside of a ship to be maintained and every job, from changing a propeller to repairing a hull valve, to be done with the ship afloat anywhere in the world means also that divers of adequate skill must be available. With the great increase of the lighter type of diving as a sport it is perhaps not unreasonable to consider the possibility of deck officers qualifying in the use of this type of gear. A further point worthy of consideration is the value of surface supplied diving equipment as fire-fighting equipment, although the converse seldom applies, and that a set or two kept aboard might prove a good insurance.

Thus naval architects and marine surveyors, by appreciating the capabilities and mobility of the modern type of diver, can substantially help towards keeping a ship afloat from her launch to the moment of her being broken up at the end of an uneventful career. Major damage caused by collision, stranding and the like must of course be excepted from this thesis although, in many cases, it is the ability of the diver which has made the return of such a casualty to dock a possibility.

THE DIVER'S OTHER ACTIVITIES

The survey and repair of ships is only one phase of the diver's activities which, in addition to the more obvious branches like wreck survey, demolition and salvage work, include surveys of the sea bed for cable routes and the like. In cases of the latter type, where for example the survey of a large area of sea mud is called for, the diver is often at a disadvantage when compared to the efficiency of instruments carried in or below a survey vessel. On a recent survey of the proposed route of a cross English Channel power cable, however, the reports of a diver gave sufficient data to form a very clear picture of the nature of the bottom as deduced from echo soundings and magnetic readings taken, from a survey craft, over a large area.

In all deep diving below 100 feet a different type of equipment becomes necessary. Mobility is of great importance to the diver both for ease of working and because, in deep diving, he is often considerable distances from his start point and has to include the double journey from base to job and back within his endurance. For this type of work re-breathing, self-contained equipment is normally used.

Work in harbors and channels is seldom carried out at a greater depth than 70 feet and the main problems, particularly in British waters, are lack of visibility and strong tidal streams. Again, partly because of the lesser physical effort demanded of the water, the modern dress is at an advantage and enables a diver to remain submerged and to work under worse conditions than formerly.

New techniques for welding horizontal structures, with all the reliance that can be placed on such work undertaken above water, are being developed; new methods of drilling rock and the use of small quantities of explosives for cutting sheet piling are being perfected and in each case the characteristics of the water are being used to assist in the operation.

The rate of increasing efficiency of modern diving equipment in such that the diver is becoming less and less dependent on his surface crew and his efficiency underwater is every bit as good as that of the ordinary workman doing the same job in the dockyard.

The margin between operating costs and income with most commercial vessels today has narrowed to such an extent that even a minor mishap, if remedied in the old conventional way with the probable use of a dry dock plus the time waiting for a berth, can turn profit into loss. Under these circumstances the modern diver must become an ever increasing factor in the field of ship repair.

Frigates, minesweepers and tugs of the British navy are now fitted with controllable-pitch propellers. The application of this type of propeller appears to have been limited—among other considerations—by difficult engineering problems in design of boss necessary to accommodate the blade operating mechanism, problems which are aggravated by the more frequent use of four- and five-bladed propellers to reduce vibration. Another feature which tends to preclude the use of controllable-pitch propellers is the high blade area ratio of propellers in high-speed ships which may prove to be beyond the capacity of controllable-pitch propellers for satisfactory operation. The high-tensile brass that was almost universally used ten years ago has been replaced in large vessels with nickel aluminum bronze. To overcome the serious erosion troubles usually experienced in small boat propellers, nylon may have application to propellers up to 5 ft. diameter.

—from MARINE JOURNAL
February 1961

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"JOURNAL OF THE FRANKLIN INSTITUTE"

J. M. BRIDGES

THE ROLE OF ELECTRONICS IN NATIONAL SURVIVAL

ACKNOWLEDGMENT

This address was presented at the Joint Meeting of the Franklin Institute, The American Institute of Electrical Engineers and the Armed Forces Communications and Electronics Association, held October 5, 1960 at the Franklin Institute by J. M. Bridges, Director of the Office of Electronics, Office of the Director of Defense Research and Engineering, Department of Defense. It is reprinted from the December, 1960 issue of "Journal of the Franklin Institute."

MR. CHAIRMAN, Ladies and Gentlemen: Being invited to address this distinguished gathering is a great honor and privilege. I heartily welcome this opportunity to discuss the importance of electronics to our national security with you people who are active in the various fields of science and engineering.

My topic is one of vital interest to every American. It is also a subject that is generally not too well understood or appreciated. We hear and read a lot these days about national survival and the strength of our military forces. But most of it concerns such things as ballistic missiles, bomber aircraft, nuclear-powered submarines and satellites. We hear very little about the fact that the successful operation of all these weapons and systems critically depends upon electronic devices and systems of fantastic complexity and precision—devices and systems, that, in almost every case, have pushed electronic technology to the limits of the state of the art and sometimes beyond. This evening I want to tell you a little more about defense electronics and its significance in our endeavor to maintain a military strength sufficient to deter communist aggression.

Perhaps the best measure of electronics' importance in defense is the amount of national effort and defense dollars being spent in this area. The military departments are currently spending around $6 billion a year for electronics research, development, engineering and production—well over one-half the total national output of our great electronics industry and almost one-quarter of the total defense expenditure for all research, development, engineering and production. Even more significant is the fact that approximately 40 per cent of all military RDT & E (Research, Development, Test and Evaluation) funds is now going into the area of electronics. This tremendous military research and engineering effort employs around 80 per cent of all the electronics scientists and engineers in this country.

Obviously I haven't time to describe, or even list, the hundreds of different research and development

programs that make up this vast national effort in electronics research and engineering—for instance, radar, infrared, computers, communications, acoustics, inertial guidance and electronic components. Nor can I take time to explain the vital part played by electronics in each of our modern military weapons and systems. Instead, let me give just a few specific examples illustrating how critically the success of our military operations depends on electronics.

The development of the NIKE-ZEUS anti-ballistic missile defense system provides a good illustration. I suspect that most people realize that difficult technical problems are involved in producing a missile with the range, speed, maneuverability and lethality it must have to intercept and destroy an ICBM warhead entering the atmosphere at perhaps twenty times the velocity of sound. But I doubt that many recognize that the complex and challenging problems of the missile's design are dwarfed by the technological difficulties involved in developing the radars and computers and the other electronic control devices required to make the NIKE-ZEUS effective.

The development of these major electronic systems, having the range capabilities, precision and speed of operation that will enable the weapon system to detect the warhead, identify it among the decoys and rocket fragments, track it accurately, solve the fire-control problem and direct the missile to an accurate interception—all in a very few short seconds—presents one of the most difficult research and engineering tasks ever undertaken in any technological area. The problem's magnitude and complexity can be seen from the fact that there are some half-million active semiconductor devices in the electronic equipments making up a single NIKE-ZEUS defense center. It is a shocking realization when we compare this system with its fantastic number of active electronic components with the antiaircraft fire-control systems of 15 years ago that, with only 500 vacuum tubes, were considered fearfully complex or even with the most modern surface-to-air antiaircraft missile system, which has about 2,000 active electronic elements.

The intercontinental ballistic missile is also typical of modern weapons' absolute reliance on electronics. It is hard to imagine that a huge nuclear warhead can be projected across 8000 miles of the Earth's surface and hit a target well within two miles of the aiming point. This represents an angular accuracy approaching one hundredth of a degree and a range precision better than three thousandths of one per cent. This remarkable guidance by the electronic sensing and computing elements in the missile and at the launcher represents one of the most advanced and sophisticated applications of electronics technology; it took thousands of man years of scientific and engineering effort to develop.

In another weapons area, the B-70 manned bomber will contain the most advanced and complex array of electronic devices ever assembled in an aircraft. It has been estimated that the development and engineering of the bombing-navigation system alone will cost close to a quarter of a billion dollars and will require 8000 to 10,000 man years of engineering. This is only one of the major electronic subsystems this advanced aircraft weapon system will need to perform its mission.

Probably the most exacting use of electronics in our whole defense program is in space developments. Certainly a space system depends more completely upon electronics than any other in civilian or military use. Once a rocket carrying a satellite into orbit leaves the launching pad, only by means of electronics can we obtain information from the space vehicle, whether it concerns the vehicle's precise location or data acquired by its various sensing instruments, most of which are themselves complex electronic devices.

In one of our current military space programs, the satellite carries equipment employing some 28,000 electronic parts—about equivalent to 100 home television receivers. To be operationally and economically feasible, this complicated equipment must operate satisfactorily in space, with no adjustmen or maintenance, for long periods of time, perhaps a year or more. Can you imagine turning on 100 television sets and letting them run continuously for a year without having to adjust one set or replace a single defective part? Attaining reliability of electronic equipment that is essential for space applications poses a tremendous engineering problem. It will call for the development of electronic components and construction techniques that are far more reliable than those available today.

I hope these few examples make it fairly clear that electronics is the keystone of our military capability and, in most cases, the controlling technology.

Now I would like to mention the critical and urgent need for more rapidly advancing electronics technology across the board. This we must do to acquire the new electronic concepts, components and techniques we need for the development of new weapons and space systems so advanced and so powerful that they will give us an undeniable—and, we hope, discouraging lead over the Soviet.

Certainly I need not belabor the point that we must maintain such a position of military and technological superiority over the communist nations. From the time Mr. Khruschchev scuttled the Summit meeting until recently, when he "declared war" on the United Nations, world events have clearly demonstrated that the only factors that might cause the communist powers to alter the frightening course of their drive toward world domination are the military strength and technological achievements of the United States and its allies.

Today the balance of military strength is in our

favor. Both the President and the Secretary of Defense have said repeatedly that this nation has the most powerful military force the world has ever known—one that is not second best to the U.S.S.R. or any other nation. I firmly believe that this is so, although I realize that in certain force postures the lead is marginal. Certainly if we are to stay ahead, we must continue to develop, produce and deploy our weapons at an ever-increasing pace. But just staying ahead is not enough. In the critical years ahead, we must strive to create entirely new kinds of weapons based on new technology—weapons that will give the West a decisive military advantage. I am not speaking of weapons that merely evolve through refinement and gradual improvement of existing weapons but, rather, of radically new ones that can significantly change the balance of power in our favor. What sort of weapons these new ones will be, I cannot say, the atomic bomb was one; the ICBM was another.

Now why do I feel that future breakthroughs in weapons are so important? Very pertinent to this is the situation I see developing in the major strategic forces that constitute our deterrent and retaliatory power, which is so vital to our national survival. Our powerful strategic striking force of manned bombers, an extremely important part of our deterrent strength, is currently undergoing a rapid transition. It is being complemented by a family of intercontinental ballistic missiles: the ATLAS is now operational, the submarine-launched POLARIS is entering the Navy's operational forces this fall, and the TITAN will be added to our operational ICBM forces the middle of next year. In addition, the development of MINUTEMAN, which has a shorter reaction time, greater reliability and better performance than ATLAS, is being developed on an accelerated schedule.

With this rapid expansion of ICBM strength, both in the United States and the U.S.S.R., it seems obvious to me that, unless disarmament negotiations are successful, there will develop within a very few years a balance of deterrent strength between the Communist and Western powers that will constitute a deadly and frightening stalemate of missile-borne destructive power. Each side will have a sufficient number of these missiles—dispersed, hidden and protected by site hardening—for a potentially complete mutual destruction, even on a "strike second" basis. When such a weapon stalemate exists, it seems most unlikely that any nation would start an all-out thermonuclear war.

Although these supersaturated forces of destruction probably constitute an excellent deterrent to nuclear attack on this country—and, incidentally, provide a tremendous incentive for the negotiation of world disarmament—it does not appear that they will significantly deter the outbreak of limited wars. It is inconceivable that any nation would risk almost certain destruction of its civilization by employing such forces in limited military conflicts. This means that our tremendous investment in bombers and intercontinental ballistic missiles will probably not keep the Soviet from continuing to nibble away, even using military force, at its long-range objective of world communism.

But, if we could definitely break this growing deterrent stalemate by acquiring some radically new weapons that would give us an overwhelming military advantage, we could not only deter all-out attack against us but might discourage continued aggression on a limited scale.

One thing that could break the balance of deterrent forces would be a truly effective system of defense against them—not one that would merely stimulate the opposition to build and deploy more missiles in an effort to re-establish the balance, but a defense system, including fall-out shelters, that could effectively protect our military, industrial and population centers against a massive, all-out attack. Almost surely the nation that first achieves such a defense would have a tremendous military and political advantage, at least until methods of countering the defense were developed or until both sides had equally effective defenses.

This discussion of total defense against ballistic missiles illustrates my point concerning the potential importance of radically new weapons based on new technology. Obviously, this is only one area where such new weapons could exert a significant and, perhaps, decisive influence on the balance of power between East and West.

In tactical warfare radically new weapons could also be extremely valuable. As I said before. it is unlikely that our strategic thermonuclear forces will prevent aggressive acts of a limited nature on the part of the communists. It is essential, therefore, that the tactical forces of our Army, Navy and Air Force be kept always at the highest possible level of efficiency. To this end, these forces should have ready to use the most advanced weapons that our scientists and engineers can provide.

Also in the area of command and control we urgently need new systems based on new concepts and new techniques. The requirements for reliability, capacity and reaction times in command and control have advanced so rapidly with the growth of weapon capabilities that current computer and communications technology is not fully adequate to meet these system needs.

Our space programs also demand electronic components and techniques that we do not have at present. I am not just sure where space activities fit into the involved picture of competition for world supremacy. It is evident that satellites orbiting the Earth have great potentialities for military use in communications, navigation, warning and surveillance and various defense agencies are vigorously pursuing extensive programs in these areas. Probably other space ventures—putting "man in space,"

probing the moon or planets or embarking on journeys beyond our own solar system—will profoundly affect our national prestige throughout the world. But the military implications of these ventures are not clear. Still we cannot afford to shut our eyes to these programs, nor to the revolting possibility that space—even outer space—may some day represent another dimension of man's battlefield. It is conceivable, for example, that space systems apart from the provision of early warning, might play an important role in establishing a fully effective defense against ballistic missiles such as I mentioned earlier. I just don't know how these things will develop—and I am not sure that anyone else knows.

To reiterate the point I have been making for the past few minutes: Radically new weapons and systems can profoundly and, perhaps, decisively influence the balance of power between the communist and free worlds. Indeed it is entirely possible that a single fundamentally new weapon could be the determining factor in our civilization's survival in the coming decades. But any such weapon will almost certainly come out of new technology rather than refinements based on current weapon approaches. Accordingly, I consider it imperative that this nation shift an appreciable amount of its scientific and engineering resources from the task of developing generation after generation of weapons that only marginally increase our total strength to the task of research and technical development on which to base the new concepts and new techniques—and, possibly, the technological breakthroughs—that will make possible the development of decisive new weapons.

Since electronics is now the most important single technology in weaponry, it is clear to me that this area should encompass the greatest expansion of this fundamental technological effort. I would expect to see in the broad area of electronics some of the great technological advances and breakthroughs that will impact significantly on our future military capability. I can't foresee what those breakthroughs will be, nor when they will occur, nor what effect they will have on the balance of world power. I *can* say, however, that throughout the country some pretty exciting things are going on in electronics research laboratories. Here are some of them: The generation and amplification of coherent light; computers that can learn and possibly "think"; microwave generators with outputs measured in megawatts of average power; thermionic power conversion; new methods of radio transmission wherein all systems elements, including the antenna, are hundreds of feet below the Earth's surface; and revolutionary concepts of solid state and cryogenic electronics that may make it possible to house in the limited volume of a space vehicle a computer with the capability of the SAGE system. Some of the many new avenues of electronics research now opening up may hold the secret of new force that could give us the desired unchallengeable lead over communism.

But, unless we put more national emphasis on research and exploratory development in electronics —and I want particularly to stress the need for additional emphasis on exploratory development—these and other promising technological advances in electronics will be far too long coming to fruition. It is not enough to expand our storehouse of knowledge through a broadened and accelerated program of fundamental research. We must carry out the applied research or exploratory development that is necessary to prove that it is feasible to apply this new knowledge to some new weapon concept. Otherwise, it may remain in the archives of scientific literature unused, perhaps forgotten by the developers of weapon systems. that is, unless it is found and used by the Soviet.

Now let me summarize the points I have attempted to bring out this evening.

First, electronics is probably the most important and most critical area of technology affecting the development of all weapons and command and control systems.

Second, our future military strength and, perhaps, our national survival may depend upon weapons that are radically new and are based on advanced or new technology rather than weapons that are mainly "warmed-over" versions of weapons now in existence or well along in development.

Third, there is an urgent need to shift a substantial portion of our scientific and engineering resources from weapons development to research and particularly to exploratory development.

Finally, because electronics is so widely used in all military weapons and control systems, a major technological advance in this area may lead to a new weapon concept that will give this country a decisive military advantage.

In closing, I would like to say that I hope and pray—as I am sure most Americans do—that a way can be found at the conference table to solve the grave problems at the root of world tension. If the contest in weapons development continues between two nations so rich in industrial and scientific resources as the U.S. and the U.S.S.R., the result will be not only a persistent and increasing drain on our civilian economy, in both dollars and scientific manpower, but a steady increase in the danger of worldwide destruction.

Speaking in Syracuse four years ago, I expressed the hope that the challenge to all mankind to conquer space would be so great that his desire to fight among his own kind would disappear. I am afraid this was merely wishful thinking. In reality, the space programs of the United States and the U.S.S.R. have had the effect of intensifying international rivalry rather than stimulating cooperative endeavors in scientific exploration.

We must keep hoping for, and working toward, a political or sociological kind of breakthrough that will lead to permanent peace among the great powers of the Earth. At the same time, we must seek the technological breakthroughs that will enable us to keep our armed services strong enough to deter military aggression on all fronts until it is possible to bring about the disarmament of nations in a safe and generally acceptable manner.

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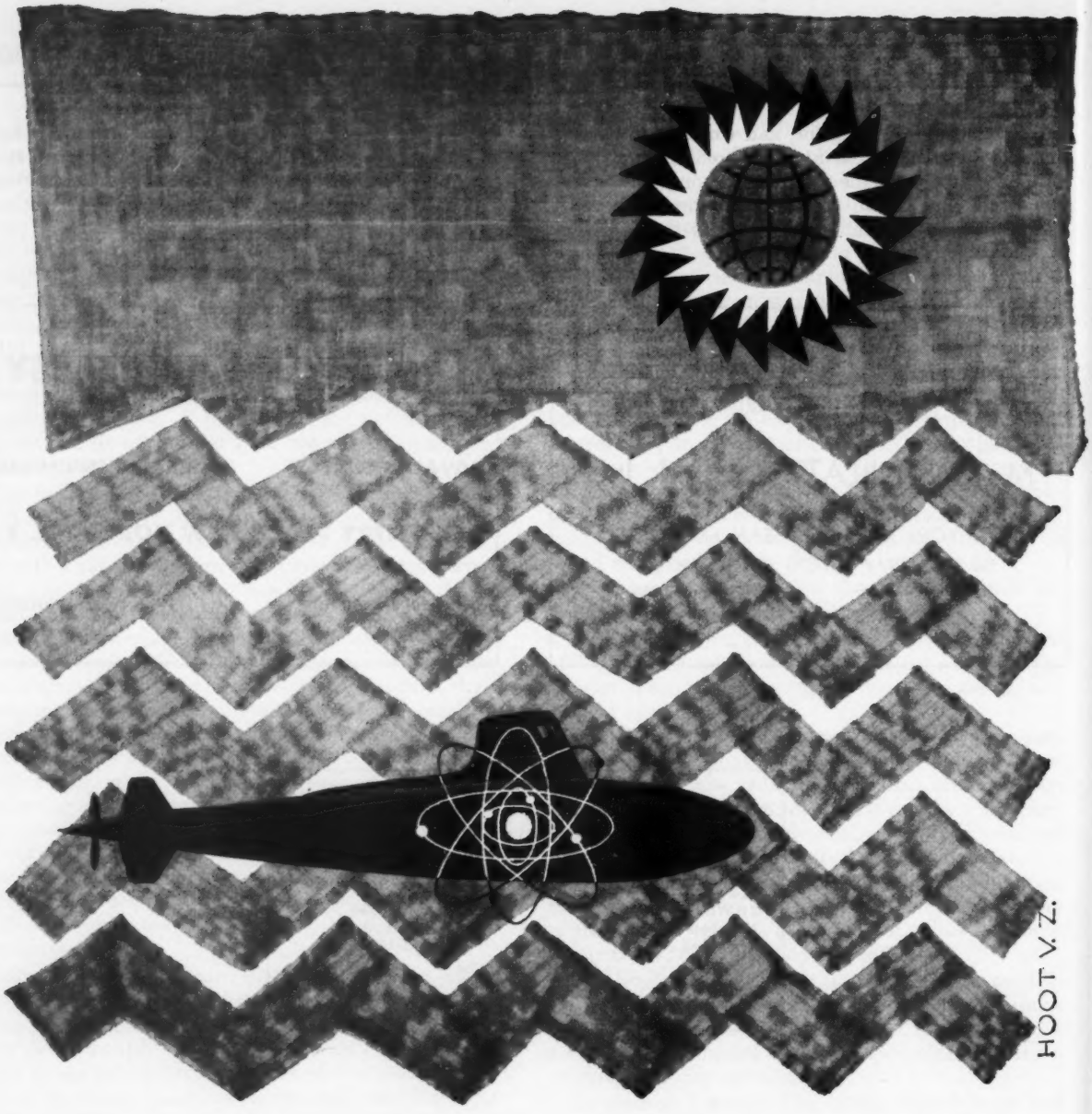

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CANADIAN DIVISION SUPPLEMENT

THE CORROSIVE BEHAVIOR OF NON-FERROUS METALS IN SEA WATER

ACKNOWLEDGMENT

This paper, reprinted from the December 1960 Transactions of the Institute of Marine Engineers, Canadian Division Supplement was the first lecture presented to the newly formed Atlantic Section (Canada) of the Institute. The author, T. Howard Rogers, Officer-in-Charge, Naval Research Dockyard Laboratory, H.M.C. Dockyard, Halifax, N.S., in presenting his paper stressed that his statements apply only to the corrosion of non-ferrous metals and alloys in sea water at atmospheric temperatures.

INTRODUCTION

For corrosion to occur four things are necessary; two electrodes, an electrolyte and an electric current. One electrode, the anode, will always have a higher solution potential than the other, the cathode. Metal will go into solution or, in other words, corrosion will occur, at the anode. This corrosion reaction will be largely controlled by the potential difference between the anode and cathode; the conductivity of the electrolyte; and the resistance of the external circuit which completes the cell. The anode and cathode of a corrosion cell may be immediately adjacent to each other, or separated by any distance, the criteria which will limit the distance will be the ability of the electrolyte and the external circuit to carry the current. There are two types of corrosion cells. One, in which the cell produces its own current because of the difference in nobility between the two electrodes, and a second where the metal at the anode is driven into solution by the application of some external source of electric current. The electrolyte can be any liquid which contains ions to carry the current through the solution. The reason corrosion is so severe in sea water is because sea water is one of the best natural electrolytes known. Those shipbuilders who have encountered corrosion in the "heads" will immediately think of another natural liquid which is a good electrolyte but fortunately it is confined to reasonably closed systems. The size of the anodes and cathodes can vary almost infinitely, either can be larger or smaller than the other but it should be remembered that a small anode in circuit with a large cathode will deteriorate at a much faster rate than will a large anode coupled to a small cathode. One further controlling factor of the corrosion reaction must be mentioned and that is the type of film which is formed on the metal surface. This film

may be a natural oxide, or some other chemical film intrinsic to the corroding metal or alloy or an artificially applied film, such as paint. The thickness of this film can be of almost any order of magnitude but it will only successfully prevent corrosion if it has three properties. It must be continuous, impervious and elastic. If these three conditions are met thickness is almost immaterial. An example of a very thin natural film, which has the three requisite qualities and which is only a few molecules thick, is that found on stainless steel; an example of a thick protective film is that found on some bronzes. Further, because the corrosion film (rust) on steel has none of these properties, steel must, before it can be used in sea water, be protected in some way. The most usual method is by paint although within the last few years the use of cathodic protection has become increasingly common. The protection of steel by non-ferrous metal coatings is not always successful in such a corrosive medium as sea water. Some natural films are self healing, and some are not, and the amount of oxygen that must be present to maintain these protective oxide films varies over wide limits. Although this lecture is considering non-ferrous metals it may be mentioned, in passing, that because the protective film on stainless steel is very sensitive to oxygen concentration, this material is often a very unsatisfactory alloy to use in sea water. Although it is not proposed to mention specifically the characteristics of the corrosion films on the alloys now to be discussed it may be accepted that the choice of metals and alloys for use in marine application is closely linked to the types of film they form in natural sea water. You will notice the word "natural" before sea water, this is important as it has been shown by many workers that aerated 3 per cent sodium chloride made up with fresh or distilled water has not the same film forming characteristics as the natural medium. This is due to the fact that small amounts of various organic compounds found in the natural product have an effect upon the formation of the corrosion film. Besides corrosion many alloys used in sea water can suffer deterioration by "impingement" attack and by cavitation damage. Both of these phenomena are caused by a mixture of electro-chemical corrosion and mechanical erosion. Without going too deeply into the subject it can be said that impingement attack is usually associated with flowing aerated water and usually has a greater electro-chemical component than mechanical. Cavitation damage, on the other hand, is due to the collapse of cavitation bubbles at an area of low pressure and usually has more mechanical component than electro-chemical. There is one other type of corrosion commonly found in the copper-base alloys which contain appreciable (over 15 per cent) amounts of zinc: dezincification. The reasons for this attack found in closely related alloys may be somewhat obscure but the final result is that the alloys end up, wholly or in local areas, as a mass of amorphous copper which has no mechanical strengh and is very porous.

ALUMINUM

Probably the most troublesome property of aluminum to the practical shipbuilder is that all aluminum alloys in the wrought form look alike. A very large number of corrosion failures in aluminum alloys, when in contact with sea water, are not due to the use of aluminum *per se* but to the issue of the incorrect aluminum alloy for the job on hand because of confusion in store keeping.

The next most common mistake, which occurs frequently in small yards which have no adequate contact with the aluminum companies or qualified naval architects, is the impression that alloys of the "Dural" (age hardening alloys containing 3-4 per cent copper) type can be used for marine application. Because the aircraft industry is based on these alloys it is an utter fallacy to think that a marine industry can be based on them also. It cannot be too strongly emphasized that they are not suitable for use in sea water and marine atmospheres and they should never be used in such locations. If the marine industry wishes to use these alloys for lockers, furniture and internal hardware, trouble will not usually be encountered, but these alloys must be kept away from sea water. It may be asked why the word "usually" was used in the last sentence. It was used because no ship is watertight, and because the most handy cleaning fluid aboard a ship is obtained by dipping a bucket over the side or hosing down from the fire mains. Aluminum mess-deck fittings made of copper containing aluminum alloys do not react very well to such behaviors, especially if they are held down by brass screws. No doubt some will suggest that the above strictures can be overcome by paint, but why use alloys which need painting and re-painting when there are aluminum alloys which will resist corrosion by sea water without this added expense.

There are two groups of wrought aluminum alloys that can be used with impunity in sea water, but it is advisable to restrict these two groups to sheet, plate and extruded shapes, and treat piping separately (see below). Further, super purity aluminum, although it has excellent corrosion resistance is not normally suitable for application in shipbuilding. The two useful groups are (a) those alloys which contain major amounts of magnesium and little silicon, and are not heat-treatable, and (b) the magnesium-silicide alloys which are heat-treatable. It is of little value to give the compositions of these alloys as they vary from country to country and supplier to supplier, but they are exemplified in Canada by Alcan 54S (N5/6) or Alcan 57S (N4) and Alcan 65S (H20). On the North American Continent Alcan 54S (AA5083) is becoming the most widely specified alloy when good corrosion resist-

ance in sea water is required. Of these two groups of alloys many will behave well even if unpainted in marine locations. As, however, the corrosion product of aluminum is very voluminous it is usually preferable to paint them as this prevents the formation of spots of aluminum oxide at areas of local pitting which unless removed are unsightly. The pitting, however, is usually superficial and rarely dangerous. Before leaving the corrosion behavior of wrought aluminum in sea water it is necessary to stress the point that the shipyard which proposes to work aluminum will have to learn some new techniques. Scantlings cannot be extrapolated from steel to aluminum or *vice versa* just in terms of mechanical properties. Some aluminum alloys, for instance, lose strength when welded and no aluminum alloy can be joined to steel in locations where the joint will be wetted by sea water without some form of insulation. Aluminum is anodic to steel in sea water and therefore when aluminum is coupled to steel and becomes wet with this liquid, unless the contacts between the two metals are insulated the steel will drive the aluminum into solution. This fact has to be accepted and must be taken into consideration wherever a composite aluminum/steel structure is built for marine use. The problem is handled in many ways. By paint, by metallic coatings, by the use of insulating materials such as canton flannel and plastic tape. On the whole, however, the subject is not one for solution by the small shipyard without expert advice. Most of the aluminum companies provide excellent consultative services for just this type of problem. Use should always be made of these consultants before bolting a "Dural" deck house to a steel deck with brass bolts with a feeling of euphoria that now, at last, things are on the move. It may be mentioned in passing that probably the best type coating that can be applied to aluminum is one of the many brands of Zinc Chromate paint. Such coatings if properly applied can be used as a base for heavy metal anti-fouling compositions which under no circumstances can be applied directly to aluminum when it is to be used in the sea. It is also advisable to treat the question of anodizing as a means of preventing the corrosion of aluminum in sea water with some care. Anodizing alone is often not very successful in preventing the corrosion of aluminum in marine locations and, in fact, if such a coating is damaged the corrosion may be greater than if the base alloy had not been so treated.

Two aluminum casting alloys will be commonly found around ships. One which contains about 10 per cent magnesium and no silicon, Alcan 350 (LM10) and another which has a silicon content of about 7 per cent and no magnesium, Alcan 135. Of these two alloys the 350 is the stronger material and if properly cast, heat treated, and with the magnesium content carefully controlled, it has a high impact resistance and it can be used very successfully in sea water. However, this alloy is very touchy and if the correct composition is not carefully maintained and the casting technique well controlled, it can, unfortunately, suffer severe stress corrosion cracking when used in marine locations. For this reason alloys with lower magnesium contents are often preferred. The silicon alloy, which has mechanical properties between the high and low magnesium alloys, is becoming very popular in the shipbuilding industry as it does not undergo stress corrosion cracking with consequent loss of strength.

The problem of piping manufactured in aluminum alloys can well be considered separately from sheet although some of the alloys may be the same. Piping will be found at least in Alcan B51S (H10), 57S (N4) and 65S (H2O) but none of these is really suitable for carrying sea water. Some effort has been made to use Alcan 57S for this purpose but sometimes the result has been catastrophic, especially if the aluminum piping carrying the sea water has been included in a system containing copper-base components. In such cases small amounts of copper salt will precipitate out on the surface of the aluminum pipe and perforation can occur in a matter of weeks. Other cases are known where this alloy in the absence of copper salts, has not stood up very well to the corrosive attack of salt water. There is no question that the piping material to use for carrying sea water is a clad alloy. The alloy most frequently used in Canada is Alcan 3S (N3) aluminum, clad inside with 72S (no U.K. equivalent) which is an alloy containing about 1 per cent zinc and which is anodic and thus protects the 3S alloy wall of the pipe. Piping made of this material has been known to last for 8 to 10 years even when used in a system that contains copper base components. It may have one drawback and that is that, as the anodic layer corrodes, large quantities of voluminous aluminum corrosion products are formed which tend to clog valves and other components with moving parts.

BRASSES AND BRONZES

Brasses and bronzes. Here, indeed, is an area of confusion. First of all what is a brass; and what is a bronze? Originally brasses were alloys of copper and zinc, and bronzes were alloys of copper and tin. Quite early in the history of metallurgy it was realized that of the two alloys the bronzes were the more corrosion resistant, were often more beautiful and had better mechanical properties. This led to the habit of the metals industry giving the name bronze to alloys which were essentially brasses but which the sales promotion staff thought would sell better and would appear to have enhanced properties were they called bronze. It would seem that high pressure salesmanship was early abroad in the metals industry. Thus, as time has gone on we are

presented with various anomalies. Two of which come easily to mind; "Tobin Bronze" which is really a second grade Naval Brass and "Tin Bronze" which would appear to be an attempt by the industry to rehabilitate the description bronze. It can be emphasized here that aluminum brass is not the same material as aluminum bronze; and further, as the series of copper-aluminum alloys commonly called aluminum bronzes seldom contain tin in appreciable amounts they are not true bronzes either. A large number of failures by corrosion of these two classes of alloys are due to inefficient ordering. If a shipbuilder orders *brass* with no qualification as to the kind of brass required he can hardly blame the supplier if he obtains the cheapest brass alloy available which will, usually, have no corrosion resistance in sea water.

BRASSES

There are two groups of brasses with which the shipbuilder will normally be concerned. The first, those of alpha, single phase, structure which can be worked cold and whose copper content is about 70 per cent. Three well known compositions are found in this group (see Table I).

TABLE I

Nominal Composition of the Alpha Brasses
(All modified by the addition of arsenic)

	Cu per cent	Zn per cent	Sn per cent	Al per cent	As per cent
Cartridge Brass	70	30	—	—	0.02 to 0.05
Admiralty Brass	70	29	1	—	0.02 to 0.05
Aluminum Brass	76	22	—	2	0.02 to 0.05

These brasses will behave excellently in sea water if, and only if, they are inhibited toward dezincification by the addition of 0.02-0.05 per cent arsenic. While it is true that some manufacturers, again no doubt for sales promotion reasons, suggest that the same result can be obtained by the use of roughly similar quantities of antimony or phosphorus, these alloys are not very frequently met with outside the U.S.A. It has been the author's experience that 0.02-0.05 per cent arsenic will be very nearly 100 per cent effective in the prevention of dezincification in these alpha alloys. In over ten years only one case of dezincification in an arsenic inhibited alpha brass has been brought to his attention. The arsenic inhibited aluminum brass alloy is a very important one as not only does it resist dezincification but it has, also, very good resistance to impingement attack by aerated sea water, a characteristic not well marked in the other two. It is undoubtedly the best of the "brasses" for use as a condenser tube.

The second group of brasses are those of two phase, alpha plus beta, structure which can be hot worked and whose copper content is about 60 per cent. Two well known compositions will be found in most shipyards. These are shown in Table II.

TABLE II

Nominal Compositions of the Alpha Plus Beta Brasses

	Cu per cent	Zn per cent	Sn per cent
Muntz metal	60	40	—
Naval brass	60	39	1

Both these alloys, except when used in very thick sections (as in condenser tube plates), are of very little use in sea water. Both of them dezincify very rapidly and to date no entirely successful inhibitor of this type of attack has been found for these two phase materials. Without going into the history of why the 60/39/1 alloy is called Naval Brass (Naval Brass is not the same as Admiralty Brass—see Table I) it can be stated without fear of contradiction that it has long outlived its name. It may be an excellent material for a wardroom bar rail but it should never be used in sea water unless the user is prepared to face continual replacements. It is used extensively in the Maritimes for small fishing craft, and the philosophy behind its use would appear to be capital cost versus repairs out of income. Let the initial cost be low and then replacements can take care of themselves. Perhaps the small boat industry like it this way?

BRONZES

There are many bronzes, and in a paper of this type it may not be necessary to do more than list the various major groups, especially as the compositions vary greatly within the groups and from manufacturer to manufacturer.

Phosphor Bronze

The phosphor bronzes, of which there are several, with tin contents between one and ten per cent, are essentially alloys of copper and tin and they are undoubtedly the copper-base work horses of the shipbuilding industry. On the whole the higher the tin content the more resistant they are to marine corrosion. They can be used successfully in sea water in both the wrought and cast forms and if they have the required mechanical strength they are excellent alloys for shipboard use. Those alloys which contain more than 5 per cent tin may need careful manufacturing control to produce the homogenized structure that is to be preferred and it is probable that those alloys to which some lead has been added, to increase machinability, may have less corrosion resistance than those not containing this element.

Manganese Bronze

There are many manganese bronzes. Some of the higher alloy types containing 3.5 per cent or more

manganese have good resistance to corrosion by sea water. However, some of the alloys that are boosted by the name "Manganese Bronze" are little more than high strength yellow brasses and they should not be used in sea water as they easily undergo dezincification and have little resistance to corrosion or erosion in this medium. No alloy designated "Manganese Bronze" should be purchased for use in marine locations unless the composition is known. If the copper content is low, the zinc high, and the other alloying elements are present in only a very small percentage the alloy is likely to have little resistance to corrosion and erosion by saline waters. If these alloys are considered as propeller materials three ranges are available.

a) "Soft" manganese bronzes: alloys with reasonable mechanical properties, high elongation and which repair easily. They have, however, little corrosion resistance.
b) "Hard" manganese bronzes: by increasing the alloying elements both in quantity and variety propellers of much higher corrosion resistance and mechanical properties can be produced. However, they need careful heat treatment if they are to be repaired successfully.
c) "Nickel" manganese bronzes: the addition of nickel to the regular compositions does give enhanced corrosion resistance but although easier to repair than the more sophisticated nickel-aluminum bronzes they cannot really compete in resistance to corrosion and erosion with such materials (see below).

Silicon Bronze

There are several silicon bronzes and some of them again have fancy trade names. These bronzes have extremely high strength and on the whole have good resistance to erosion in marine environments. However, some are better than others and, contrary to suggestions in over enthusiastic promotion literature, they can suffer deterioration when used in sea water.

Aluminum Bronze

The modern aluminum bronzes and those which are often called nickel-aluminum bronzes are good. They are the best alloys for high duty propellers. However, again, the correct one for use in a specific location is a matter for expert advice. There is no question that if a shipbuilder is required to provide large "wheels" for ships in these materials the recognized propeller manufacturers should be consulted and cheap "off the shelf" items should be avoided. These bronzes do, however, have two characteristics which often cause them to be viewed unfavorably *vis-a-vis* the high class manganese bronzes. They are difficult to cast and difficult to repair and although these factors tend to make their initial price and maintenance cost rather high their superior behavior usually makes their use economically sound.

There are many other "bronzes" some of which are recommended for condenser tubes and other locations where sea water is present. It is impossible to cover them all but just because there are so many of them and their mechanical properties, coefficient of heat transfer and corrosion behavior vary so widely the small shipbuilder should always consult some independent agency before accepting, out of hand, all the masses of sales promotion literature which will pass across his desk.

COPPER ALLOYS CONTAINING MAJOR AMOUNTS OF NICKEL

Here we enter another area of embarrassment and again the nomenclature of these alloys often bewilders many suppliers. First, there are the *cupro-nickel* alloys. These alloys, of which there are two common ones, contain roughly 20 or 30 per cent nickel and find their major use in condensers. The second group are the *copper-nickel-iron* alloys. Again there are two, one containing approximately 5 per cent nickel and the other around 10 per cent. They find their main use in lines carrying sea water to heat exchangers and in fire main systems where a lighter material than galvanized iron is required. The third group contains more nickel than copper and most of them fall into the ranges covered by the general description "Monel Metals" or their near relatives the "Inconels."

TABLE III—*Copper-Nickel Alloys (Nominal Compositions, USA)*

	Cu per cent	Ni per cent	Fe per cent	Zn per cent	Mn per cent
70/30 Cupro-nickel	60–70	29–33	0.4–0.7	1 max.	1
80/20 Cupro-nickel (A)	74 min.	19–23	0.6 max.	1 max.	1
80/20 Cupro-nickel (B)	70 min.	19–23	0.6 max.	3–6	1
5 per cent Copper-nickel-iron	91	5.5–6.5	1.05–1.5	—	0.3–1.0
10 per cent Copper-nickel-iron	86.5 min.	9–11	0.5–2.0	1 max.	1

Monel metals. See trade literature available from The International Nickel Companies.

Cupro-Nickels

The cupro-nickel alloys came into extensive use in the form of tubes for heat exchangers. These materials are very resistant to impingement attack, general corrosion and pitting when used in sea water. However, again, purchase of these alloys should be made with care as unless they contain of the order of 0.4 per cent iron their corrosion resistance in sea water will not be good. Further although the 80/20 alloy may be cheaper it is rarely economic to buy it if the water speeds are likely to

be in the range of 15 ft per second or more. Although these materials were originally developed for condenser tubes they are now finding considerable use in other parts of the ship where maximum resistance to corrosion by sea water is a primary requirement.

Copper-Nickel-Iron Alloys

There are two alloys in the range which are available commercially. They are the 5 per cent nickel/copper-base alloys with about 1.5 per cent iron and the 10 per cent nickel/copper-base alloys with 0.75-2 per cent iron. The 5 per cent copper-nickel-iron alloy is now finding considerable use in auxiliary piping systems carrying sea water in ships of many types. It is being used extensively for fire mains and sanitary services and it has a corrosion resistance several times that of copper. This alloy, however, requires careful working and when fitting flanges by methods which require heating, the temperatures should not be allowed to rise above 1,300 deg. F. The 90/10 alloys with an iron content of about 1.75 per cent is now being used quite extensively as a condenser tube in the U.S.A. This material makes a good condenser tube and it has been shown to be an excellent material for use in badly contaminated sea water as its tendency to pit under such conditions is low.

Monel Metals

These materials are used where a requirement for maximum resistance justifies the expense. They all have excellent resistance to corrosion and erosion to aerated sea water, but like the stainless steels are susceptible to attack by the oxygen concentration cell type of corrosion if they are used where the sea water can become stagnant and low in oxygen content; such as at crevices and areas shielded from oxygen diffusion. They are also very noble metals and this should not be forgotten when they are used in composite structures.

COPPER

The high natural resistance of copper to corrosion by stagnant or slowly moving sea water is well known. This good behavior, however, falls down when copper, especially copper pipe or tube, is located where it will be in contact with aerated sea water moving at about 4-5 feet or more per second. All coppers have little resistance to impingement attack. There are several forms of copper and it can be taken as a fairly general rule that there will be no difference in the corrosion or erosion behavior in sea water of those coppers which contain small amounts of oxygen, phosphorus or arsenic, or which contain more than one of these minor additions, and those which do not. These additions are made for reasons quite unconnected with the corrosion behavior in any media. If, however, we exclude sea water, copper pipe or tube, when used for such services as oil lines, refrigeration systems, low and high pressure air lines, etc., copper has no "strikes" against it.

GUNMETALS

On the North American Continent there are several alloys which can be considered under the designation gunmetal (see Table IV); although the use of this word is not so common as it is in the United Kingdom. Of these materials some are better than others when specified for cast components to be used in the presence of sea water.

TABLE IV—*Composition of Gunmetals*

	Cu per cent	Sn per cent	Zn per cent	Pb per cent	Ni per cent
"G" Bronze	88	10	2	—	—
Ounce metal	85	5	5	5	—
Navy "M"	88	6	4.5	1.5	—
Nickel-tin bronze (Inco Ni-Vee)†	88	5	2	—	5
INCO (Improved)	R	6-7	1.5-2.5	0.1-0.5	5-5.5
B.N.F.	87.5	7.5	2	3.0	—

† Registered Trade Mark.

The last two alloys are those recently developed by the British Non-ferrous Metals Research Association in the United Kingdom and the International Nickel Company. These latter alloys have been introduced because they have improved casting qualities and the improved Ni-Vee alloy was produced to give more rapid ageing and to avoid the quench cracking which often occurs in the normal composition nickel-tin-bronze during heat treatment.

At the moment there is little or no Canadian experience of how these new alloys behave towards corrosion by sea water. The B.N.F. have assessed their alloy by "jet impingement tests" and consider it will rank in good agreement with the corrosion behavior in sea water of the 88/10/2.

These "gunmetals" again present an area of confusion which in this case seems to revolve more around their casting behavior than their corrosion resistance. It is the author's experience that ounce metal, although easy to cast and frequently used in locations where it is in contact with sea water, does not have the corrosion resistance of "G" bronze and nickel-tin bronze when used for high duty components such as high speed pump casings. Further, tests have shown that Navy "M" is less resistant to sea water corrosion than "G" bronze. However, as this comparison has been made in the somewhat rarefied atmosphere of fighting ships it would not be in order to criticize too violently the use, in sea water, of the leaded materials except to say that on the whole the presence of lead can be considered to

depress the corrosion resistance. It would be fair to suggest that shipbuilders and naval architects specifying these alloys should weigh carefully the casting, pressure tightness, and operational temperature requirements, against the degree of corrosion resistance required. It also may be pointed out that pump casings, etc., that "weep" slightly can often be readily made serviceable by a few coats of paint; whereas, a tighter casting made of a less corrosion resistant material may result in an expensive replacement.

TIN AND LEAD ALLOYS

Tin has good corrosion resistance to sea water and if a tin coating fails it will more likely be due to the poor quality of the coating, which has allowed galvanic attack to occur at holes in the coating, than to the tin. The potential of tin is very close to that of iron and in sea water its polarity can vary. Sometimes it will be more noble than steel and at times the reverse may be the case. On the whole, however, a good tin coating will have good resistance to corrosion by sea water. Similar remarks can be made about lead. On the whole it resists corrosion quite well, but as it is commonly used alloyed in fairly large quantities with some other element many cases of its use must be assessed in the light of the operational conditions required, as all lead alloys are not suitable for all the uses they are sometimes required to carry out in sea water. One of the greatest areas of trouble is the means of application if the lead is used as an anti-corrosion coating. There are many ways of coating steel with lead and some are better than others.

There are many alloys of tin and many alloys of lead and they vary considerably in their usefulness to the shipbuilder but generally the reason for using the different ones depends only to a minor extent on their corrosion behavior.

ZINC

Except as anodes in some cathodic protection systems, zinc sheet or components manufactured of pure zinc are rarely found in marine locations. Galvanized iron, however, is often found in the shipbuilding industry and if the coating is properly applied the protection of steel for *limited periods* will be satisfactory. The ability of galvanized iron to resist corrosion by sea water will depend on the quality of the adherence, freedom from pin holes and the evenness of the coating.

This completes the survey of the major non-ferrous metals used in the shipbuilding industry. Many points have been omitted and much more detailed expositions of the behavior of the various materials will be found in the author's "Marine Corrosion Handbook" published in Canada by the McGraw-Hill Book Company. As there was no preprint of the paper those who heard the lecture will find the printed version rather longer than the original; for this the author craves their indulgence.

Motors and transformers of high efficiency and small size are being developed, the Soviet News Agency reports, using plastics incorporating magnetic particles.

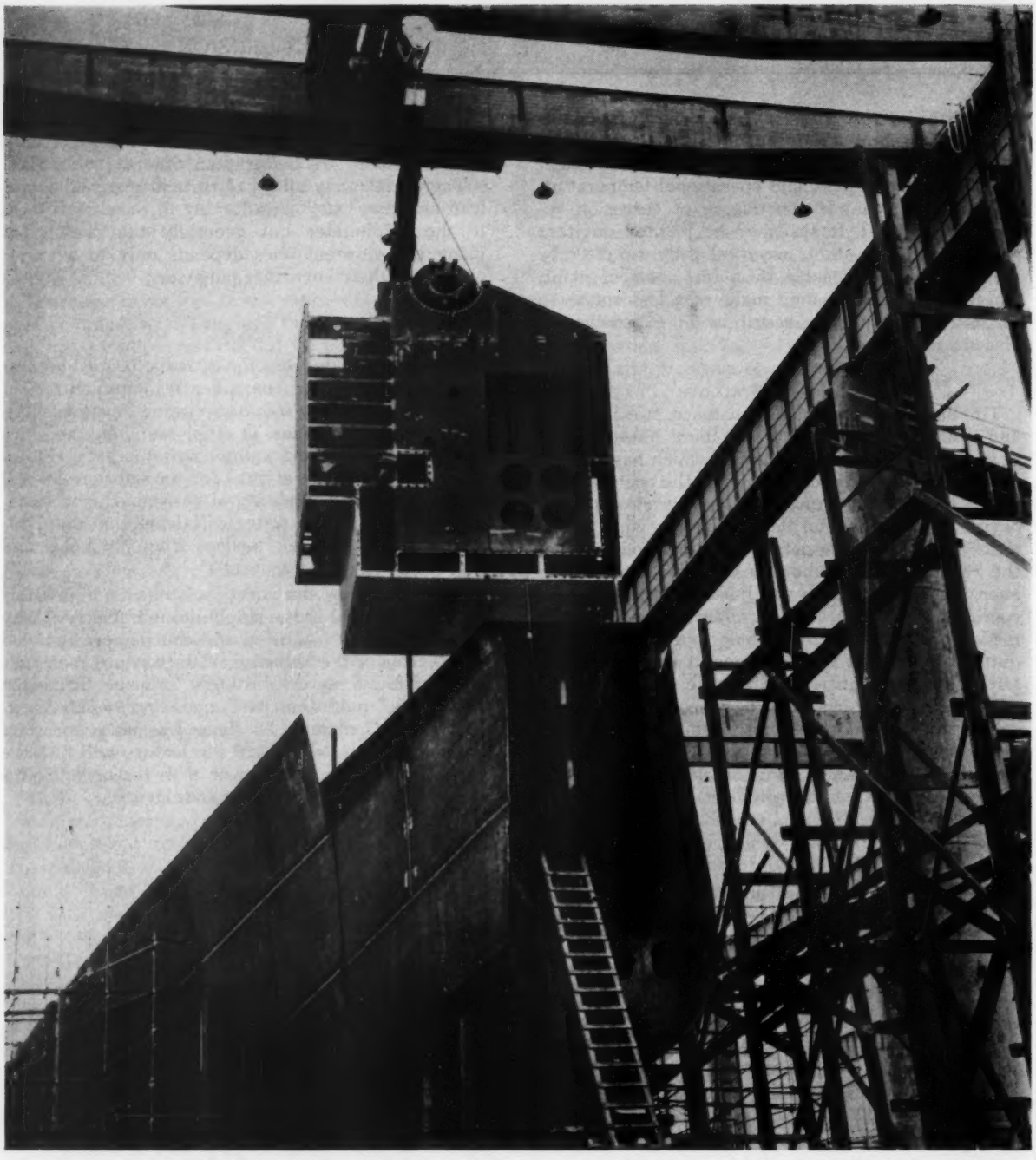
The fact that these magnetic plastics are good insulators as well as good magnets, the Soviets say, brings design characteristics "close to the ideal theoretical level."

With "practically all" surface and pulsation losses eliminated, they claim, it is possible to increase motor capacity substantially while decreasing size and weight. (PRODUCT ENGINEERING, Jan. 9, 1961, Page 8)

FRENCH ALTER STEELMAKING

Injection of oxygen-lime powder is sweeping through French steel mills. For some time, a 30-ton OLP converter has operated on three shifts in the Saar. This converter uses high-phosphorus hot metal. Furnace-lining life averages 200 heats. Other benefits include less siliceous slag and controlled dephosphorization. At Dunkirk, hot-hematite metal will soon be refined in 140-ton converters, using the OLP process.

—METALWORKING NEWSWEEK



Another C-E Vertical Superheater Boiler goes aboard. Accorded worldwide acceptance, units of this design are now being installed on an ever-growing number of vessels of all types. New U. S. Navy ships equipped with C-E Vertical Superheater Boilers include AOE, LPH and DDG type vessels.

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SOME FORMULAS FOR PIPING DESIGN

THE AUTHOR

is Professor of Mechanical Engineering at the U. S. Naval Postgraduate School, Monterey, California, and formerly Director of Research for Midwest Piping Company, Inc. He is the holder of a Ph.D. degree from the University of Minnesota and is the author of many papers in the field of Mechanical Engineering, several of them on the subject of piping. He serves on the Mechanical Design Committee of the American Standards Association Committee on Code for Pressure Piping and on the ASTM Committee A-1 on steel. He is a member of ASME, ASTM, ASEE, and Sigma Xi.

SOME OF THE MORE advanced digital computer programs for the analysis of the flexibility of high temperature piping systems provide, as a part of their outputs, deflections (i.e., cold to hot movements) of as many points in the configuration as the user may wish. These deflections consist of three displacement and three rotation components. Inspection of the computer output frequently reveals that at some intermediate point one of the deflection components has a "desired" value and it is of interest to locate this position. The most obvious example of this is the case where the vertical motion of one point described in the output is downward while that of the next point is upward. In this case it is of interest to locate the intermediate point which experiences no vertical displacement so that a so-called "rigid" hanger (rather than a spring hanger or a constant support hanger) may be located at this point with a saving of cost and with additional assurance that the actual behavior of the system will be like the predicted behavior so that clearances will not be compromised.

In the following, several formulas will be obtained for locating such points if they occur within the length of straight pieces of pipe. The formulas become too complicated to exhibit explicitly if the points occur in elbows or pipe bends, but the methods outlined here may be applied in such cases. Also, the matrix formulations in the following analysis may be of interest in themselves.

NOMENCLATURE

$s =$ distance from A to B (see Fig. 1)
$\alpha, \beta, \gamma =$ direction cosines of segment AB (see Fig. 1)
$EI =$ flexural rigidity of pipe cross section
$\mu =$ Poisson's ratio (taken as 0.3 in numerical calculation)
$\kappa =$ effective stress concentration for cross shear (taken as 2.0 in numerical calculation, see text discussion)
$\lambda = 2(1+\mu)\kappa$
$r_o =$ outside radius of pipe
$r_i =$ inside radius of pipe
$t =$ wall thickness of pipe
$d = 2r_o - t =$ mean diameter of pipe
$\rho^2 = (d^2+t^2)/8 =$ square of radius of gyration of pipe
$e =$ total unit thermal expansion (in/in)

$I =$ unit 3×3 matrix $= \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

$\sigma = [\alpha\ \beta\ \gamma]$

$\eta = \begin{bmatrix} 0 & \gamma & -\beta \\ -\gamma & 0 & \alpha \\ \beta & -\alpha & 0 \end{bmatrix}$

$D_A = \{\delta, \theta\} = \{\delta_1, \delta_2, \delta_3, \theta_1, \theta_2, \theta_3\}$
$D_B = \{\Delta, \Theta\} = \{\Delta_1, \Delta_2, \Delta_3, \Theta_1, \Theta_2, \Theta_3\}$
$F_A = \{F, M\} = \{F_1, F_2, F_3, M_1, M_2, M_3\}$
(In the preceding three definitions, δ and Δ denote displacements, θ and Θ denote rotations, F denotes forces, and M denotes moments.)
$B_{AB}, B_{CB}, B_{CA} =$ transfer matrices (see Reference 1.)

$X = s\{\tilde{\sigma}, 0\} = \{\alpha s, \beta s, \gamma s, 0, 0, 0\}$
$f = \sigma F = \alpha F_1 + \beta F_2 + \gamma F_3$
$m = \sigma M = \alpha M_1 + \beta M_2 + \gamma M_3$
$\sim$ (tilde) indicates the transposed of a matrix
$\{\ \}$ (braces) indicates a column matrix
Thus, $\tilde{\sigma} = \{\alpha, \beta, \gamma\}$
Also, α, β, and γ are direction cosines and a_i, b_i,
c_i $(i=1, 2, 3)$ are coefficients employed in the final application given in the paper.

Dr. E. G. Baker [2] gives a formula for the influence coefficient matrix at point C of piping element AB (Figure 1) and this can be exhibited in the form

$$C_C = \begin{bmatrix} s^3(I-\tilde{\sigma}\sigma)/12 + s\rho^2[(1-\lambda)\tilde{\sigma}\sigma + \lambda I] & 0 \\ 0 & s(I+\mu\tilde{\sigma}\sigma) \end{bmatrix} \div EI.$$

The second term in the upper left position is not present in Baker's expression and it accounts for axial and cross shearing deformations which ordinarily are quite small. If the computer program with which one is working does not include these influences, the corresponding terms should be omitted from the formulas which follow; this will imply the omission of the asterisk terms in the formulas of Table 1. Also, it should be noted that with the cross shearing effect present, slopes will not refer to tangents to the locus of centers of the circular cross sections, but rather to normals to the planes of the cross sections.

The parameter λ in this expression depends on the value of κ which denotes an effective stress concentration for cross shear. This quantity does not appear to have been discussed in the literature. Using the stress function given by Sokolnikoff [3] in formulas given by Love [4], leads to the evaluation

$$2-\left(\frac{r_o^2-r_i^2}{r_o^2+r_i^2}\right)/(1+\mu) \leqq \kappa \leqq 2+\left(\frac{r_o^2-r_i^2}{r_o^2+r_i^2}\right)/(1+\mu)$$

and it seems reasonable to take the value $\kappa=2$ for practical purposes. Apparently several computer programs use this value. Incidentally, the VQ/Ib formula of elementary theory also leads to the value $\kappa=2$ for thin wall pipe. Thus, with $\mu=0.3$, we have $\lambda=5.2$.

Using the theory given in [1], we have

$$D_B = \tilde{B}_{AB}D_A + eX + C_B F_B$$
$$\tilde{B}_{AB}D_A + eX + (\tilde{B}_{CB}\, C_C B_{CB})(B_{BA}F_A)$$
$$\tilde{B}_{AB}D_A + eX + \tilde{B}_{CB}C_C\, B_{CA}F_A.$$

L. Crawford [5] using a different notation gives a similar result. Using the definition of the transfer matrix as given in [1], we can write

$$\tilde{B}_{AB} = \begin{bmatrix} I & s\eta \\ 0 & I \end{bmatrix};\ \tilde{B}_{CB} = \begin{bmatrix} I & \tfrac{1}{2}s\eta \\ 0 & I \end{bmatrix};\ B_{CA} = \begin{bmatrix} I & 0 \\ \tfrac{1}{2}s\eta & I \end{bmatrix}$$

and substituting into the preceding equation and working out the details yields the six formulas shown in Table I. In doing this, it is useful to observe the following two simplifying relations:

$$\sigma\eta = 0,\quad \eta\eta = \tilde{\sigma}\sigma - I.$$

The formulas for Δ_1, Δ_2, and Δ_3 are most useful. In the usual application an iterative solution for s is convenient. Thus, for example, we would write the formula for Δ_3 in the form

$$s = \frac{(\Delta_3-\delta_3) + s^2(\alpha M_2 - \beta M_1)/2EI + s^3(F_3 - \gamma f)/6EI}{\gamma e + \beta\theta_1 - \alpha\theta_2 + [\lambda F_3 - \gamma(\lambda-1)f]\rho^2/EI}$$

In the following numerical illustration a greater number of significant digits are exhibited than is warranted by the accuracy of the input data; this is done so as not to obscure the details of the computation. Suppose that the computer output for two successive points of a cold reheat system in a utility plant is as follows:

Point	Displacements (inches)			Rotations (radians)		
20	4.611	−2.997	0.363	0.00027	0.00648	−0.00070
21	6.581	−3.465	−2.258	0.00015	0.00483	−0.00046

TABLE I—*Deflections and rotations as functions of parameter s.*

$$\Delta_1=\delta_1+s\{\gamma\theta_2-\beta\theta_3+\alpha e+[\lambda F_1-\alpha(\lambda-1)f]^*\rho^2/EI\}+s^2(\gamma M_2-\beta M_3)/2EI-s^3(F_1-\alpha f)/6EI$$

$$\Delta_2=\delta_2+s\{\alpha\theta_3-\gamma\theta_1+\beta e+[\lambda F_2-\beta(\lambda-1)f]^*\rho^2/EI\}+s^2(\alpha M_3-\gamma M_1)/2EI-s^3(F_2-\beta f)/6EI$$

$$\Delta_3=\delta_3+s\{\beta\theta_1-\alpha\theta_2+\gamma e+[\lambda F_3-\gamma(\lambda-1)f]^*\rho^2/EI\}+s^2(\beta M_1-\alpha M_2)/2EI-s^3(F_3-\gamma f)/6EI$$

$$\Theta_1=\theta_1+s(M_1+\alpha m)/EI+s^2(\gamma F_2-\beta F_3)/2EI$$

$$\Theta_2=\theta_2+s(M_2+\beta m)/EI+s^2(\alpha F_3-\gamma F_1)/2EI$$

$$\Theta_3=\theta_3+s(M_3+\gamma m)/EI+s^2(\beta F_1-\alpha F_2)/2EI$$

Note: the terms marked with an asterisk should be omitted if axial and cross shearing deformations are not to be counted.

The forces applied at point 20 by segment 19-20 to segment 20-21 are:

Point	Forces (pounds)			Moments (inch-pounds)		
20	−291	−31	−2874	36151	244605	40901

The coordinate differences are $x_{21}-x_{20}=425.832$ inches, $y_{21}-y_{20}=-46.218$ inches, $z_{21}-z_{20}=0$. The positive z-direction is vertically upward. Thus, the direction cosines of segment 20-21 are $\alpha=0.99416$, $\beta=-0.10790$, $\gamma=0$. The pipe is 24 inches outside diameter and has 0.687 inch wall thickness. Thus $\rho^2=67.996$ in^2. Also, the reciprocal flexural rigidity (1/EI) is $1.0476\cdot10^{-11}$ pounds^{-1} inches^{-2} and we take $\mu=0.3$ so that $\lambda=5.2$. Thus, to locate the point for which $\Delta_3=0$, we have

$$s=\frac{-0.363+s^2(247077)\,(5.238\cdot10^{-12})+s^3(-2874)\,(1.746\cdot10^{-12})}{-0.00647129+(-14945)\,(67.996)\,(1.0476\cdot10^{-11})}$$
$$=56.002-1.997\cdot10^{-4}\,s^2+7.742\cdot10^{-7}\,s^3$$

Successive iterants are 56.002, 55.512, 55.519, and the latter value repeats. Thus, a rigid hanger (i.e., one that provides full constraint against displacement in the z-direction but does not inhibit other deflection components) may be placed at a point 4′-7½″ from point 20 along the line toward point 21 and this will save hanger expense and give greater assurance that actual behavior will be like predicted but will not tend to invalidate the flexibility calculations which presumed that there was no variable force applied at this point.

In stationary installations the principal usefulness of this development would be in locating points where rigid hangers could be used in place of the more expensive types. In shipboard piping installations, however, where inertia effects due to ship motion are imposed upon the piping, they may also be used to locate points where stays and sway bracing may be applied to equilibrate such forces without restraining the thermal expansion of the piping. In installing sway bracing, it may be convenient to orient it in a direction other than one of the coordinate directions; let this direction have direction cosines $\bar{\alpha}$, $\bar{\beta}$, and $\bar{\gamma}$. Then the component of D_B in this direction is $\bar{\alpha}\Delta_1+\bar{\beta}\Delta_2+\bar{\gamma}\Delta_3$. The formulas in Table I may be written in the form

$$\Delta_1=\delta_1+a_1s+b_1s^2+c_1s^3$$
$$\Delta_2=\delta_2+a_2s+b_2s^2+c_2s^3$$
$$\Delta_3=\delta_3+a_3s+b_3s^2+c_3s^3$$

where the coefficients a_1, a_2, a_3, b_1, b_2, b_3, c_1, c_2, and c_3 are those shown in Table I. Thus, to determine the value of s which locates the point which has a given value, $\bar{\Delta}$, of displacement in the $\bar{\alpha}$, $\bar{\beta}$, $\bar{\gamma}$ direction, we need only solve the following equation by iteration.

$$s=\frac{\bar{\Delta}-(\bar{\alpha}\delta_1+\bar{\beta}\delta_2+\bar{\gamma}\delta_3)-s^2(\bar{\alpha}b_1+\bar{\beta}b_2+\bar{\gamma}b_3)-s^3(\bar{\alpha}c_1+\bar{\beta}c_2+\bar{\gamma}c_3)}{\bar{\alpha}a_1+\bar{\beta}a_2+\bar{\gamma}a_3}$$

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Anaconda announces a new high-strength copper-nickel-iron tube alloy that makes possible substantial economies in feedwater heaters

Research metallurgists of Anaconda American Brass Company have developed, after three years of intensive effort, a new high-strength copper-nickel-iron alloy—Cupro Nickel, 30%-707—for heat exchanger tubes in power plant feedwater heaters.

Alloy 707 has mechanical properties comparable with those of a premium high-strength alloy now commonly used, and retains its strength at elevated temperatures—allowing working stresses up to 15,200 psi at 600° F. Thus, in an important area of high-temperature heater application it provides material-cost advantages.

And as these high mechanical properties are for the metal in the *annealed* condition, Alloy 707 tubes can be readily cold worked—can be expanded into tube sheets and formed into tight U-bends.

MECHANICAL PROPERTIES of Cupro Nickel, 30%-707 (nominal composition, copper 64.15%, nickel 30.00%, iron 5.25%, manganese 0.60%) are as follows:

Tensile Strength, min, psi	74,000
Yield Strength, (0.5% Extension under Load), min, psi	36,000
Elongation, % in 2", min	30
Expansion of Tube Inside Diameter with Tapered Pin, %, min	30

STRENGTH AT ELEVATED TEMPERATURES. Extensive tests at room and elevated temperatures show that design stresses given below can be used for Alloy 707:

Maximum Metal Temperature, °F	Maximum Allowable Stress Values in Tension, psi
100	18,300
150	17,800
200	17,500
250	17,100
300	16,800
350	16,400
400	16,100
450	15,900
500	15,600
550	15,400
600	15,200

WELDABILITY. Alloy 707 can be welded by the same methods used for regular 30% cupro nickel.

CORROSION RESISTANCE. Alloy 707 has the same high resistance to stress-corrosion cracking and the same excellent resistance to corrosion by salt water as regular 30% cupro nickel.

FOR MORE DETAILED INFORMATION on this new high-strength tube alloy, Cupro Nickel, 30%-707, see your Anaconda representative, or write: Anaconda American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

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ON-OFF MAGNETISM

Out of Du Pont Company's fundamental research, as reported at the sixth annual Conference on Magnetism, has come discovery of a new metallic compound—chromium manganese antimonide—with unique magnetic characteristics. Temperature changes trigger the compound's transformation: below a point predetermined by chemical composition, the material is non-magnetic; heated above that point, it becomes magnetic. By slight changes in the proportion of chromium, the transition point can be adjusted—according to experiments to date, across a range of from near absolute zero to above 100 degrees C. Apparently the magnetic change occurs because distance between the compound's atoms determine the line-up of inner magnetic forces, and this condition varies as the material expands and contracts with temperature variation. Du Pont reports that laboratory investigations of the metallic substance are shedding light on previously unknown aspects of magnetism, will extend knowledge beyond.

—Research/Development Magazine

"SHIPBUILDING AND SHIPPING RECORD"

MARINE NUCLEAR PROPULSION IN GREAT BRITAIN

ACKNOWLEDGMENT

This article was written by Captain C. W. Mains, R.N. and is reprinted from the December 29, 1960 issue of "Shipbuilding and Shipping Record."

IF WE LEAVE ASIDE the question of submarines, in which nuclear propulsion is an essential characteristic of design and development, where does marine nuclear propulsion stand to-day? Much has and is being written on this subject and to the casual but interested spectator it is hard to find an answer to this question. To him, opinion seems to vary widely from cautious optimism to the deepest pessimism.

What is the present situation so far as merchant ships are concerned?

Among the many people and organizations throughout the world concerned with this subject, there are few who doubt that this new power source will ultimately replace the use of oil for all but the smallest power plants. This optimism stems from the belief that nuclear fuels will eventually produce power at prices considerably less than that of oil and that the capital costs of nuclear power installations will be progressively reduced as developments are made and experience is obtained. It is often asserted that the development of nuclear propulsion is attended by serious risks but to those concerned with them, developments in shipbuilding and marine engineering have always been accompanied by elements of risk, indeed there are few technological advances which are not accompanied by hazard of one sort or another.

There is no doubt that we are entering a period in marine propulsion in some ways as revolutionary as that which saw the change from sail to steam. While it must be admitted that there is only a slight resemblance between them, since the former was accomplished by engineers against the established technique of the master mariner, the present conflict is between the economists and cautious engineers on the one hand against the nuclear engineer on the other.

QUESTION OF COST

Whatever may be the shortcomings of nuclear propulsion at the present time, it does not suffer from any lack of analysis of what it may or may not offer. It is very doubtful if the introduction of the steamship was subjected to such searching treatment, but technological advances make this inevitable since nuclear power requires a relatively much more costly installation and is attended by risks to which the steamship was not. Moreover, the

wider aspects of its development puts it beyond the capacity of the most powerful commercial concerns to contemplate without Government assistance. Nevertheless, the comparison with the change from sail to steam is similar since the pioneering British steamship owners would not have been able to survive the early days had they not had government financial backing in the shape of mail contracts for regular services.

The general economic considerations associated with these analyses into the introduction of nuclear propulsion are mainly concerned with the additional costs, both capital and running, required for a nuclear-propelled ship. Against these must be balanced the additional cargo capacity and increased speed that nuclear propulsion may be able to offer. While all these variables have to be assessed, the advantages at the present time are very near the margin only for a large high-powered ship and, from the operational point of view, nuclear power today only appears to bestow great endurance. Important as this may seem, no particular commercial merit can in general be claimed on this score when oil can be readily obtained throughout the world. It is, of course, true that in certain remote areas, where the problems and difficulty of supplying fuel are great, nuclear power confers particular advantage. It is in this light that the conception of the Russians in constructing the icebreaker *Lenin* shows up to greater effect than the American cargo ship *Savannah*, both of which are fitted with pressure water reactors which are at present very far from being economic. Although we read of projected commercially operated submarines, such a development must be regarded for the time being as an interesting but only long term possibility.

It is frequently maintained that to take advantage of nuclear power, a ship must have a high annual utilization. While this would certainly be a desirable feature for an entirely new application, to replace ships already engaged in established trades, it does not state the problem correctly. The primary consideration here must be to increase the prevailing utilization by either carrying more cargo without increasing the size of the ship or by increasing its speed with a corresponding increase in the operating costs. The only way in which the annual utilization exerts a direct effect upon the comparative economies between a nuclear and a conventionally propelled ship is through the annual energy consumption which may be higher with a higher utilization but not necessarily so.

To explain this, let us look at three well-established types of ship, the tanker, dry cargo vessel and passenger liner. So far as tankers are concerned, which have a very high utilization, advantage cannot always be taken of the potential for carrying additional cargo if the bunker fuel is saved. Zone loading regulations allow the ship to load deeper in certain parts of the world, and on many runs this permits the ship to achieve a lighter draft by the time she meets the more severe restrictions (*i.e.* on a trip from the Middle East to Europe). Moreover, only very small returns can be expected by increasing the power above that of a conventional tanker. This is because, in order to achieve an increase of speed, it would be necessary to fine the lines of the ship and go to twin screws which would greatly increase the capital costs.

While being subjected to the same loading restrictions as the tanker, generally speaking the dry cargo ship is specially designed for a particular trade, its utilization being governed by the requirements of cargo handling. It is, moreover, subject to certain definite limitations associated with the trade it is engaged upon. One of these limitations is the physical size of the ship imposed by the ports it is desired to use. While the cargo liner might benefit from an increase in power these limitations would, except for certain specialized bulk cargo ships, seem to place it among the last so to do.

On some passenger ship routes, however, the provision of nuclear power may well offer many advantages since these ships have a much higher shaft horse power and domestic load which, together with their fine lines, will enable them to absorb an increase in power. Thus the fast passenger ship with a lower utilization compared with that of, say, a tanker shows up rather better in the application of nuclear power.

The first merchant ship to reap full benefit from the advent of nuclear power, is therefore likely to be the passenger ship, but for obvious reasons this type of ship may well be the last to be so fitted. From the point of view of a prototype, which is unlikely to be economic in any case, it would not seem to matter greatly what type of ship is selected, though the choice appears to be between the bulk, liquid or dry cargo carrier. The American construction of a passenger/cargo ship as their first prototype was probably influenced by considerations of publicity and prestige since the ship will be seen soon in a greater number of ports in the world than would a tanker.

Enriched fuel is a necessary requirement for all small reactors and at the present time the costs are high; this is chiefly due to the limited production of the fuel elements but these will almost certainly eventually be less than the existing oil fuel prices, particularly if it becomes possible to use plutonium for fuel. It follows, therefore, that the higher the annual energy consumption of the conventional ship the greater this potential saving will become. Economically, this saving will have to be balanced against the additional capital cost of a nuclear ship and this will, of course, show to particular advantage in the case of the ship of high power. In high-powered conventional ships, there are certain running costs, such as boiler maintenance, which will be saved in the nuclear ship; indeed the high capi-

tal cost of the nuclear ship stems to some extent from the fact that only limited maintenance can be carried out. Until more practical experience is obtained of this, very little can be said about it but it is reasonable to expect that high-powered nuclear installations will show to advantage here. The fact remains that the present problem is undoubtedly the high capital cost of the nuclear installation and that the development of prototypes is expensive but, as experience is gained in constructional technique and the necessary special facilities required, the costs of production should decrease.

If Britain had not been faced with a shortage of fuel after the war, it is almost certain that, as a maritime nation with a shipbuilding industry which is both vital to her commerce and economic life, she would have directed her efforts in the applications of nuclear power as the Americans have done towards smaller installations which have a direct application in marine propulsion. The expected shortage of fossil fuel has not materialized but there are no signs that she intends to alter her present aim of developing large reactors suitable for the generation of electric power. The reasons for this may be many and varied but the chief reason must be the apparent lack of economic incentive. This is a situation which has arisen before at various turning points in the advance of marine propulsion; nevertheless, progress has been made. The steam turbine fell to Britain, thanks largely to the drive and private fortune of one man, though we were not so fortunate with the diesel engine which followed.

Our ability today to analyze technical situations has been accompanied by the ability to confuse and frighten ourselves by the morass of technical difficulties these analyses are bound to produce. With this comes an insidious tendency to procrastinate and the possibility of practical development becomes more and more remote. Let us make no mistake about it, in no field of development has a paper study or design ever been a substitute for the practical lessons learned from the construction of actual hardware. When one considers the hardware in this particular field it is important to be clear on the status of reactors at the present time. Broadly they can be classified into three groups:

(1) Those that have been built and operated and whose technology is established.

(2) Those whose feasibilty has been established and whose technology is sufficiently understood to warrant a program of experiments.

(3) Those which exist as conceptions only.

The first group is the only one that can be contemplated in furthering the constructional and operating know-how of marine nuclear propulsion. In this group are the water, and the organic-moderated reactors. The large British gas-cooled, graphite-moderated reactors suitable for marine propulsion still require technological extrapolations which place them in the second group. This leaves only two types, the experience and understanding of which substantially rests in the hands of American industry whose designers must, to a large extent at present, be prisoners within the confines of their own successful experience. Mistakes are damaging to the progress of nuclear engineering and very expensive. It is not surprising, therefore, to find progress in this field confined to a series of experimental reactors. The point to be noted though, is that the technological and engineering knowledge of reactors can only be progressed through a carefully planned program of construction and operation. Since our knowledge in these matters is developing all the time, the point at issue, so far as nuclear propulsion is concerned, is at what time do we take the decision to build and operate a nuclear ship?

PROTOTYPE SHIPS

As has already been explained, it must be accepted that a prototype ship will be both expensive and out of date by the time she is in service but the answer to this question should not be governed solely by considerations of reactor technology as there are other factors to be taken into account. With this in view the Admiralty set up an advisory committee in 1957 under the then Civil Lord of the Admiralty, which included representatives of shipbuilders, shipowners, and the U.K. Atomic Energy Authority. This resulted in the Admiralty seeking propositions from British industry (many of whom had close associations with American industry) for nuclear propulsive machinery of some 50,000 S.H.P. On receipt of these propositions, a technical subcommittee was established to make a critical assessment of them and a similar 20.000 S.H.P. installation for a commercial tanker. Of the seven submissions made by industry, three were based on American technology, one partly on American technology, two on gas cooling and one on a novel principle of steam cooling with heavy water moderation. In this article, it is not necessary to describe in detail each of these submissions; the outcome was that it was decided to invite tenders for nuclear-powered installations based upon a closed cycle boiling water reactor and an organic liquid moderated reactor. This invitation, based upon a 65,000-ton d.w. tanker, was made by the Ministry of Transport because the responsibility for merchant shipbuilding had in the meanwhile been transferred there from the Admiralty. That is where the matter is now and is likely to remain for a little longer while the tenders are being examined before a decision on future progress can be made.

Britain with her long history of maritime achievement is naturally interested in this matter of nuclear propulsion and the frontiers that need to be pushed back to achieve it. Among these, apart from

considerations of technology and economics, are the acceptance of nuclear-powered ships in port, health, safety and insurance. Countries with the earliest nuclear ships will be creating important precedents in matters of maritime law, acquiring constructional skill and operating knowledge besides achieving prestige in doing so. Developments in nuclear propulsion have been rapid when one considers the progress that has been made in the last decade and a stage may now have been reached where constructional and seagoing experience may have an important bearing on the early attainment of competitive marine nuclear propulsion. The immediate beneficiary of a limited program for designing, building and operating nuclear ships would be, of course, the shipbuilders and allied engineering industries. To them, the experience to be gained would offer the greatest possibility of technical and commercial superiority over their rivals in other countries. As nuclear propulsion for commercial ships has not yet reached the point which presents an economic advantage, the shipowners are not for the present enthusiastic.

Many of the heavy engineering industries in Great Britain have already invested heavily in nuclear research and development and teams have been working for some years with the U.K. Atomic Energy Authority. While some of the major shipyards have linked up both practically and financially with the established nuclear consortia both in this country and the U.S.A., up to the present time this is as far as they have gone. Britain has the ability and the administrative machinery and the preliminary safety regulations have been agreed to on an international plane.

There are, of course, a number of arguments in favor of waiting until reactor technology is a little further advanced; and the precise moment when to enter the field will need careful judgment, but the acquisition of skill in nuclear engineering related to ship construction and operation is a factor which should not be ignored.

Official U. S. Coast Guard Photos

Admiral Will addresses the Annual Banquet on Rejuvenation of the American Flag fleet of dry cargo ships.

"APPLIED MECHANICS REVIEW"

WATER WAVES

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INTRODUCTION

THE APPEARANCE of the water when disturbed by waves has fascinated both casual and scientific observers for a long time. Recent articles and books such as Bascom [1] and Carson [2] summarize the physical characteristics of waves in a popular manner. The regular patterns from local disturbances in otherwise calm water, the everchanging aspects of wind-driven waves, and the tremendous power evident in storms have challenged the analytical talents of many of these observers. Over the years the literature has grown to such an extent that it is fortunate that several excellent recent works are available to serve as a collection, correlation, and unified presentatiton of past efforts of investigators. Wehausen [3] has recently completed a thorough presentation of the analytical forms of waves. Stoker [4] combines the mathematical theory with physical interpretation to a wide range of water-wave phenomena. Lighthill [5] covers the special field of river waves from the analytical viewpoint. The practical effects of water waves in ship design have been summarized by Saunders [6] and Johnson [7]. Characteristics of actual ocean waves and the basis for forecasting are given by Svendrup [8], Bigelow [9] and Bracelin [10]. Recent developments in the statistical evaluation of water waves and the needs for future research in connection with long-range ship design development programs are given by Pierson [11].

Since there are already in existence ample reviews of the early literature on water waves, no attempt will be made in this review to provide an extensive bibliography—even though many of the original reports may be quite applicable today. Rather it is intended that some indication be given of the current activity and persons engaged in various aspects of water waves. The review is further limited to those water-wave phenomena in which gravity plays a major role. For convenience, a division into three categories will be used: (a) waves generated by a discrete disturbance, (b) oscillatory waves, and (c) wind-generated waves.

WAVES GENERATED BY DISCRETE DISTURBANCES

Many waves can be traced to a well-defined origin such as an explosion or boundary upheaval, motion of a pressure source through or over the water, flow over an obstacle or the addition of large quantities of additional water to a bounded system. Such waves are usually regular in form both in appearance and repeatability. They have the characteristics of various types of analytical forms of water-wave theories, partly from the "simplicity" of the problems and partly because the physical evidence may be directly correlated with the analytical forms.

The plop of a pebble in a still pool produces a fascinating set of waves familiar to everyone. On a larger scale this becomes the devastating local waves of a major underwater explosion. The prediction of wave form and height for large underwater explosions has been the subject of recent study with the advent of nuclear explosions. The effect of the explosion may be represented by a sudden change in height of the water surface which is released at time zero. The form of waves produced in the two-dimensional problem check fairly well with experimental results, Prins [12], Kranzer [13] considers also the problem where the explosion is represented by a localized pressure, suddenly applied. The agreement with experiment in both two- and three-dimensional problems is good. The explosion can be represented by impulses in pressure or initial wave of equal energy, but exact matching will require further work in assigning the portion of the total explosive energy which is transferred to the formation of waves.

In the formation of tsunamis there is a massive shift of boundary over a large area. Although the motion may not be very great, the area and total energy involved may be phenomenally large compared to artificial disturbances such as man-made explosions (at least up to the present). The result in deep water is a very long wave of low amplitude which may not even be noticed by ships at sea. However, the piling of this energy upon obstacles, such as the shoreline, greatly increases the height of the waves to cause severe damage on anything in its way, Bernstein [14] and Roberts [15].

Seismographs will give ample evidence of earth tremors which might be possible sources of tsunamis, Gutenberg [16], but not many of these tremors generate waves of dangerous magnitude. The deep water wave formed has a low amplitude but very great length (high speed and long period). Thus the forecasting of probable areas of dangerous waves following an earthquake or similar disturbance at sea is difficult (because of the small wave height) and must be done with reasonable speed (because of the rapid advance of the waves). A network of stations has been put in service in the Pacific which is designed to detect the passage of such long period waves. Interpretation of the amplitude, time delay from suspected origin and period provide a basis of warning to potential danger areas, Van Dorn [17].

Waves somewhat like the tsunami of the ocean are sometimes generated on a smaller scale by the passage of relatively sudden pressure changes associated with severe storm conditions. The Great Lakes regions and North Sea areas have experienced this type of wave to a serious extent. Also, the excessive tide rise within tropical storms is associated with this type of disturbance. Wiegel [18] provides a recent analysis of the form and magnitude of such waves generated by a moving low-pressure area.

Flow conditions in rivers and channels involve special wave problems due to the restrictions to the motion and the increased effect of damping due to boundary friction. Lighthill [5] provides a recent summary emphasizing the energy relationships in the significant properties and methods of analysis for tidal bores, roll waves, standing waves, flood waves and similar phenomena. Stoker [4] shows the feasibility of using the basic hydrodynamic equations for flood stage determinations and similar river wave problems. This is made possible through the effective programming of the inputs and boundary conditions for specific problems on large-scale automatic computational devices so that the exact equations may be solved by a step-by-step process.

Waves accompanying the motion of a ship through the water are typical of a different type of discrete disturbance. Here the moving body continually supplies energy to the wave motion which spreads out from the ship and gradually dissipates at a great distance. Saunders [6] gives a recent summary of this type wave, covering the mechanism of the wave formation, special effects of restricted water and the corollary effect of wave making on the resistance of the ship. Recent work by Pond [19] extends the work on analytical representations of ship forms to determining moments and pressure waves accompanying a submerged body. Borden [20] determines the potential function for hydrofoil-type vessels in shallow water which are related to the surface waves and subsurface pressure waves. De Prima [21] and Hunziker [22] examine the free surface wave form caused by a moving sumerged object. The application of automatic computational machines to the ship wave problem by Di Donato [23] and Hershey [24] is indicative of the progress that may be made, with restrictions of manual calculations practically removed.

OSCILLATORY WAVES

Many of the simple wave forms can be reflected from a beach or other barrier to present a pattern of oscillatory waves. However, the special class intended here is composed of those generated where the water is basically enclosed and is excited by an adjoining disturbance. The key to the formation of such waves is that the disturbance possess some energy in the frequency bands near the natural frequencies of the enclosed body of water. Familiar examples occur in the hand-carried water pail or the dining car coffee cup.

The possibility of such oscillations in bays, lakes and harbors depends upon size, shape and depth of water. A study of particular types has been made by Carr [25] and McNown [26] from both the analytical and experimental model approaches. The determination of the natural frequencies for more

complicated forms of harbors or lakes can be made by the method of finite differences, Stoker [4].

An area of widely different application of the same principles may be noted in the sloshing of liquids in containers. High interest in the effect of liquid propellants in missile dynamics has led to considerable study of the motions, Eulitz [27], and methods of damping of fluids with free surface in conditions of forced oscillation, Eulitz [28] and Miles [29].

WIND GENERATED WAVES

It is obvious to the most casual observer that wind blowing across a water surface causes waves. These waves are small at first and increase with size as the wind persists and as the observer moves downwind. If the wind dies down, the smaller ripples quickly vanish, but the longer waves persist for some time. A more exact description of sea surface wind waves and the actual mechanisms by which the energy is transferred from the wind to the water are far more complex than such casual viewing might suggest.

Boundary-layer conditions in the shear flow of the air across the water and air pressure fields induced over the wave contours can both provide generating forces for waves. Ursell [30] presents a fairly complete survey of the theories of wind-wave generation. Recent contributions to the field have been made by Phillips [31], Burling [32], and Friedman [33]. Many sizes and proportions of waves exist simultaneously in the wind-driven sea. With each varying gust of air exciting new waves and adding to existing ones, there is little possibility of forming orderly progressions of uniform waves. A precise description cannot be given in terms of specific wave heights or periods because of the ever-changing pattern. Instead, the sea is described by the relative energy level as a function of the period of the waves.

Analytical models to represent such a sea surface in a statistical manner have been developed by Longuet-Higgins [34], Neumann [35,] Pierson [36, 37], St. Denis [38], and Barbyshire [39]. These all recognize the existence of a spectrum of waves in a real wind-generated sea, and they differ mainly in the manner of distributing and summing-up the components of the total spectrum. Actual wave records at sea have been difficult to obtain and require lengthy analysis, but enough data have been obtained from direct measurements to basically confirm the analytic representations, Neuman [40], Pierson [41] and Kinsman [42].

Current efforts are being directed toward refinements in these descriptions of wind waves. Measurements of actual sea surface by sterophotogrammetric methods, Marks [43], analysis of sun glitter and other visual clues, Cox [44], have provided data for defining the directional distribution of the wave energy spectrum, Munk [45] and Pierson [46]. Direct superposition of component waves in the random sea analytical models leads to excessive heights, since no allowance is made for the limitations of breakers. Recent results of work by Pierson [47], Milne-Thompson [48] and Tick [49] on nonlinear theory show significant limitations to the simple spectrum. Methods of forecasting particularly slanted toward the highest waves existing in given conditions have been examined by Chappalear [50], Walden [51], and Bretschneider [52] with considerable success in correlation with actual occurrences. In general, the current state of analysis of the wind-generated waves has fostered such progress in the art of forecasting the sea conditions that real aid is possible to marine navigation in planning best routes for shipping, James [53].

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Proposals for the establishment of a Defense Electronics Management Center to control the supplies of all electrical and electronics materiel for all military services, are expected to win immediate approval by the Secretary of Defense. The center would be staffed jointly by the military services, report to the Defense Secretary through the Armed Forces Support Council, and operate under the Secretary's direction. As planned, the DEMC would manage some 650,000 items with an inventory value of about $1-billion. Included would be resistors, capacitors, connectors, electron tubes, crystals, coils, transformers, antennas, wire and cable, headsets and other electrical and electronics parts.

—from ARMED FORCES MANAGEMENT
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COMMANDER S. R. HELLER, JR., USN

THE EFFECT OF GEOMETRY ON THE ELASTIC PROPERTIES OF CONSTANT CROSS-SECTION BEAMS UNDER SYMMETRICALLY DISTRIBUTED LOADS

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INTRODUCTION

THE DESIGN of structures to withstand dynamic loads can be considerably simplified if the concepts of *equivalent static load* and *dynamic-load factor* are used. Indeed, the design of structures to withstand static loads can also be simplified if an *equivalent uniform load* is used.

For the static case, the problem is solved by developing, in advance of the design, a series of relationships between elastic properties caused by possible forms of loading and those caused by a uniformly distributed load. For the dynamic case, an additional step is necessary to allow for the differences in reaction of a structure to the different rates of application of load.

Definitions

The load acting on a structure can be expressed as the nondimensional ratio of the applied force at any instant to the maximum value of this force; this ratio is called the **disturbance.** The ratio of the strain in the structure caused by the **dynamic** application of a load to the strain caused by the **static** application of the **same** load is termed the **response factor.** The maximum numerical value of the response factor is called the **dynamic-load factor.** Within the proportional limit of the material, the dynamic-load factor represents the ratio of the static load to the peak dynamic load for the **same strain.** Thus the **equivalent static load** is the product of the dynamic load and the corresponding dynamic-load factor. The **equivalent uniform load** is merely

that uniformly distributed load which causes the **same** maximum stress (strain) as does the actual load.

Assumptions

To simplify theoretical analysis, it is assumed that the structure can be idealized as a system with a single degree of freedom. Thus it is possible to solve the simplified differential equation corresponding to the load-time history and obtain the dynamic-load factor. This assumption is valid provided:

1. The time variation of the load has only a small amount of high-frequency content, OR
2. The load is proportional to one of the normal-mode (of vibration) functions.

It follows then that the product of the peak dynamic load and the corresponding dynamic-load factor will give an equivalent static load which, if applied to the appropriate single-degree-of-freedom system, will result in approximately the same maximum deformation and same maximum stress as produced by the actual loading on the actual structure.

Analysis

Undamped simple systems have been analyzed, and basic dynamic-load factors for a variety of different load-time histories have been presented.† Spatial load distribution was not considered in these studies; only the load-time history was. In the analysis of the impact of a planing hull in waves, however, spatial load distribution was studied.** In this work Jasper noted the similarity of the measured load distribution resulting from the impact to a versed sine. He also observed that, for this case of impact, the load distribution seemed to traverse the bottom of the hull girthwise, progressively exposing every point of the transverse members to the peak load.

Jasper then derives a *load-distribution factor* which relates the peak load and length of unsupported span to that *uniformly distributed load* which produces the *same* maximum bending moment (stress). In keeping with normal experience, the distributed load is positioned with the peak at midspan and symmetry is retained. The result of these two concepts is:

$$p^* = p_o \times F_D \times F_L \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where

F_D is load-distribution factor which depends on shape of distribution, length of unsupported span, and degree of fixity at ends,

F_L is dynamic-load factor which depends on load-time history,

p^* is the equivalent static uniformly distributed load used for design, and

p_o is the maximum load per unit length the structure experiences.

Different types of impact give rise to different load-time histories, different magnitudes of p_o, and different shapes of load distribution. It is with the last that this paper is concerned. Several different simple shapes of symmetric load distributions are studied, and their elastic properties are derived.

LOAD DISTRIBUTIONS

For all shapes studied, the origin of coordinates is taken at the left end of the beam, the coordinate of length x is positive to the right, and the coordinate of elastic deflection y is positive upward. For this orientation of coordinates and for peak load at midspan with symmetry of load retained, the usual relation between bending moment, curvature, and flexural rigidity is

$$EI\frac{d^2y}{dx^2} = -fM_o + x\int_0^{\frac{\beta L}{2}} p\,dx - Q_x \quad \ldots\ldots\ldots (2)$$

where

E is modulus of elasticity,

f is degree of fixity at ends, $0 \leqq f \leqq 1$,

I is moment of inertia,

βL is length of span, $0 \leqq \beta \leqq 1$ (see Figure 1),

M_o is fixed-end moment,

p is load distribution (positive downward),

Q_x is moment of load distribution between origin and x about x (positive counterclockwise).

Figure 1 is a schematic representation of the various load distributions studied. From Figure 1 it is seen that

$$Q_x = \int_0^x p(x-\xi)d\xi \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where ξ is the intermediate coordinate shown in Figure 1, $0 \leqq \xi \leqq x$.

Consider a beam of constant cross section and length βL loaded with a distribution p. Equation (3) is substituted in Equation (2), and the first two

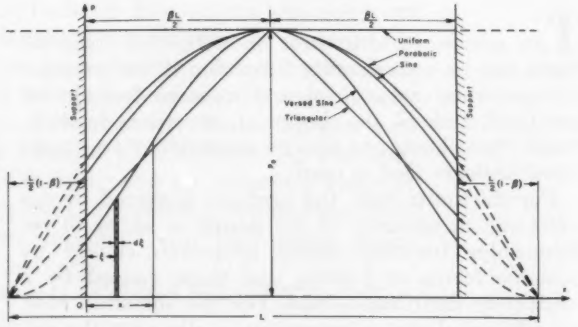


Figure 1. Schematic Representation of Various Symmetric Load Distributions.

†Frankland, J. M., "Effect of Impact on Simple Elastic Structures," David Taylor Model Basin Report No. 481, April 1942.

**Jasper, N. H., "Dynamic Loading of a Motor Torpedo Boat (YP 110) during High-Speed Operation in Rough Water," David Taylor Model Basin Report No. C-175, September 1949.

integrations of Equation (2) are performed. The resulting system of equations involves bending moment, slope, and deflection, respectively.

$$EIy'' = -fM_o + x\int_o^{\frac{\beta L}{2}} p\,dx - \int_o^x p(x-\xi)d\xi \quad \ldots\ldots (2a)$$

$$EIy' = -fM_o x + \frac{x^2}{2}\int_o^{\frac{\beta L}{2}} p\,dx - \int dx \int_o^x p(x-\xi)d\xi + A \quad \ldots\ldots (2b)$$

$$EIy = -\frac{fM_o x^2}{2} + \frac{x^3}{6}\int_o^{\frac{\beta L}{2}} p\,dx - \int dx \int dx \int_o^x p(x-\xi)d\xi + Ax + B \quad \ldots\ldots (2c)$$

where primes indicate differentiation with respect to x.

The constants of integration can be determined without regard for the degree of fixity at the ends by the use of the boundary conditions:

$$y' = 0 \text{ at } x = \frac{\beta L}{2} \text{ [Symmetry]}$$

$$y = 0 \text{ at } x = 0 \text{ [Unyielding supports]} \quad \ldots\ldots (4)$$

The first of Equation (4) will yield A in terms of the fixed-end moment; the second will produce B without further complications. If complete fixity is now used (f=1) and y' is set equal to zero at x=0 in Equation (2b), A is determined without involving M_o. Then M_o can be evaluated uniquely. Finally, this value of M_o can be substituted in Equation (2a) to give an expression for bending moment.

Uniform Distribution

Precisely because the uniform distribution is the datum to which all other distributions will later be referred, it will be studied first.

The distribution is given by

$$p_u = p_o \quad \ldots\ldots (5a)$$

The fixed-end moment is $\frac{p_o(\beta L)^2}{12}$ and the bending moment is:

$$M_x = -\frac{fp_o(\beta L)^2}{12} + \frac{p_o(\beta L)x}{2} - \frac{p_o x^2}{2} \quad \ldots\ldots (5b)$$

Inspection of Equation (5b) shows that the maximum *positive* bending moment occurs at *midspan* $\left(x = \frac{\beta L}{2}\right)$, and the maximum *negative* bending moment occurs at the *ends* (x=0, βL). The magnitudes are

$$\text{Max. Pos. } M_x = \frac{p_o(\beta L)^2}{8}\left(1 - \frac{2f}{3}\right) \quad \ldots\ldots (5c)$$

$$\text{Max. Neg. } M_x = -\frac{fp_o(\beta L)^2}{12} \quad \ldots\ldots (5d)$$

This leads to the fixity for equal maximum bending moments:

$$f_u^* = \tfrac{3}{4} \quad \ldots\ldots (5e)$$

For $f < f_u^*$, the maximum bending moment is positive and is at midspan; for $f > f_u^*$, the maximum bending moment is negative and at the ends.

The equivalent uniformly distributed load is, of course, w; the load-distribution factor F_D is unity.

Isosceles Triangular Distribution

The distribution is given by

$$p_t = 2p_o\left(\frac{x}{L} + \frac{1-\beta}{2}\right) \text{ for } 0 \leqq x \leqq \frac{\beta L}{2} \quad \ldots\ldots (6a)$$

$$p_t = 2p_o\left(\frac{1+\beta}{2} - \frac{x}{L}\right) \text{ for } \frac{\beta L}{2} \leqq x \leqq \beta L$$

The fixed-end moment is $\frac{p_o(\beta L)^2}{12}\left(1 - \frac{3\beta}{8}\right)$, and the bending moment is for $0 \leqq x \leqq \frac{\beta L}{2}$:

$$M_x = -\frac{fp_o(\beta L)^2}{12}\left(1 - \frac{3\beta}{8}\right) + \frac{p_o(\beta L)x}{2}\left(1 - \frac{\beta}{2}\right) - p_o x^2\left(\frac{1-\beta}{2} + \frac{x}{3L}\right) \quad \ldots\ldots (6b)$$

As before, the maximum positive bending moment occurs at midspan, and the maximum negative bending moment occurs at the ends. The magnitudes are

$$\text{Max. Pos. } M_x = \frac{p_o(\beta L)^2}{8}\left[1 - \frac{2f}{3} - \beta\left(\frac{1}{3} - \frac{f}{4}\right)\right] \quad (6c)$$

$$\text{Max. Neg. } M_x = -\frac{fp_o(\beta L)^2}{12}\left(1 - \frac{3\beta}{8}\right) \quad \ldots\ldots (6d)$$

From Equations (6c) and (6d) the fixity for equal maximum bending moments is obtained:

$$f_t^* = \tfrac{3}{4} \cdot \frac{1 - \frac{\beta}{3}}{1 - \frac{3\beta}{8}} \quad \ldots\ldots (6e)$$

For $f < f_t^*$, the maximum bending moment is positive and at midspan; for $f > f_t^*$, the maximum bending moment is negative and at the ends.

Now, if Equations (5c) and (6c) are equated, the uniform load for the same maximum positive bending moment (at midspan) is given by:

$$\frac{w}{p_o} = 1 - \frac{4-3f}{3-2f} \cdot \frac{\beta}{4} \quad \ldots\ldots (6f)$$

Similarly, the equating of Equations (5d) and (6d) leads to the uniform load for the same maximum negative bending moment (at ends):

$$\frac{w}{p_o}=1-\frac{3\beta}{8} \quad \ldots\ldots\ldots\ldots\ldots\ldots (6g)$$

For $f \leqq f_u^*$, Equation (6f) defines the load-distribution factor F_D; for $f \geqq f_t^*$, Equation (6g) defines F_D. For $f_u^* < f < f_t^*$, there is no clear definition of F_D since fixities in this range yield the maximum bending moment for the uniform load distribution at the ends and for the triangular load at midspan.

Similar treatment of the parabolic, sine, and versed sine distributions leads to results which differ only in detail. These results are summarized in Table 1. Selected items of Table 1 are shown graphically in Figures 1 through 6, inclusive.

COMPARISON OF RESULTS

Even a casual study of Figures 1 through 6, inclusive, discloses a rough similarity of the curves. The ordinates of curves corresponding to the various load distributions tend to diminish as distance from midspan (increasing β) increases just as the distributions themselves do. At least for a major portion of the β-abscissa (and in general for all β), the curves corresponding to the different load distributions are aligned in the same manner as are the distributions, which is to say that the properties of the parabolic distribution approach most nearly those of the uniform distribution. Then comes the sine which is followed by the versed sine with the triangular showing the greatest divergence. Even the inflection point and the reverse curvature of the versed sine distribution are retained in its derived properties although the reverse curvature is less pronounced there.

What is possibly more startling than the foregoing generalities is not readily apparent from the figures but is easily seen after close scrutiny of Table 1. Excepting only the moment of load Q_x/p_o and fixity for equal maximum bending moments f^*, the geometric and elastic properties of the various

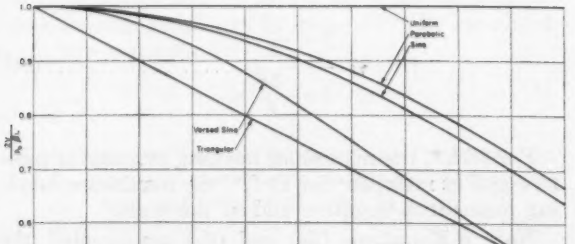


Figure 2. End Reaction as a Function of Unsupported Length.

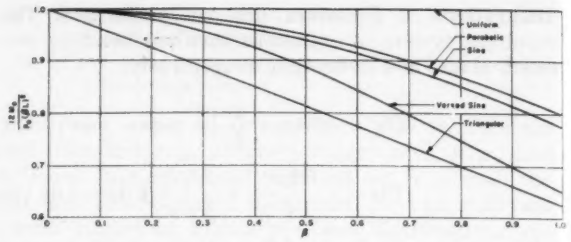


Figure 3. Fixed-End Moment as a Function of Unsupported Length.

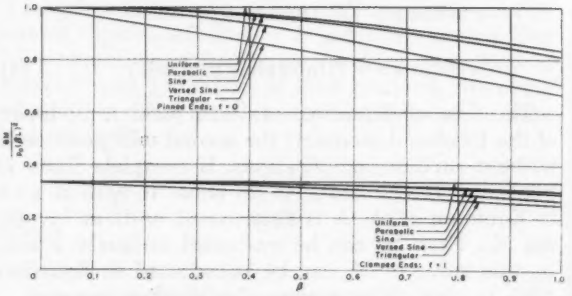


Figure 4. Maximum Positive Bending Moment as a Function of Unsupported Length.

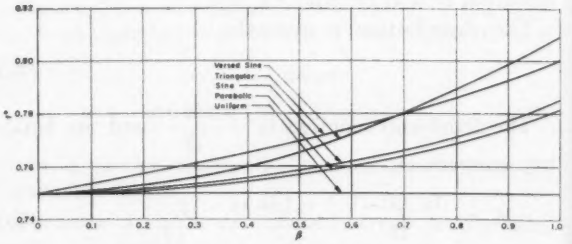


Figure 5. Critical Fixity as a Function of Unsupported Length.

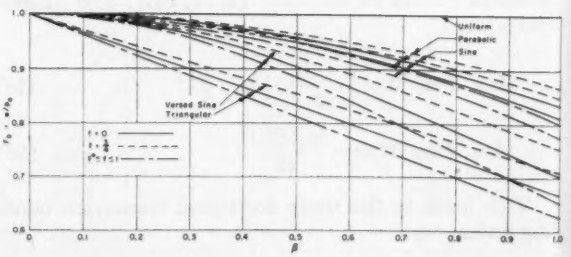


Figure 6. Load Distribution Factor as a Function of Unsupported Length.

TABLE I—*Summary of Geometric and Elastic Properties of Various Symmetrical Load Distributions*

TABLE I—*Summary of Geometric and Elastic Properties of Various Symmetrical Load Distributions*

Parameter \ Type of Distribution →	Uniform	Isosceles Triangular	Parabolic	Sine	Versed Sine
Distribution $\frac{p}{p_0}$ ↓+	1	$2\left(\frac{x}{L}+\frac{1-\beta}{2}\right)\Delta\leq x\leq\frac{\beta L}{2}$ $2\left(\frac{1+\beta}{2}-\frac{x}{L}\right)\frac{\beta L}{2}\leq x\leq\beta L$	$1-\left(\frac{2x}{L}-\beta\right)^2$	$\cos\pi\left(\frac{x}{L}-\frac{\beta}{2}\right)$	$\frac{1}{2}\left[1+\cos 2\pi\left(\frac{x}{L}-\frac{\beta}{2}\right)\right]$
End Reaction $\frac{2V}{p_0\beta L}$ ↑+	1	$1-\frac{\beta}{2}$	$1-\frac{\beta^2}{3}$	$\frac{\sin\frac{\beta\pi}{2}}{\frac{\beta\pi}{2}}$	$\frac{1}{2}\left(1+\frac{\sin\beta\pi}{\beta\pi}\right)$
Moment of Load $\frac{Qx}{p_0}$ ↳+	$\frac{x^2}{2}$	$x^2\left(\frac{1-\beta}{2}+\frac{x}{3L}\right)$	$x^2\left(\frac{1-\beta^2}{2}+\frac{2\beta x}{3L}-\frac{x^2}{3L^2}\right)$	$\frac{L^2}{\pi^2}\left[\cos\frac{\beta\pi}{2}+\frac{\pi x}{L}\sin\frac{\beta\pi}{2}-\cos\pi\left(\frac{x}{L}-\frac{\beta}{2}\right)\right]$	$\frac{L^2}{4\pi^2}\left[\frac{1}{2}\cos\beta\pi+\frac{\pi x}{L}\sin\beta\pi+\frac{\pi^2x^2}{L^2}-\frac{1}{2}\cos 2\pi\left(\frac{x}{L}-\frac{\beta}{2}\right)\right]$
Fixed End Moment $\frac{12\,M_0}{p_0(\beta L)^2}$ ↳+	1	$1-\frac{3\beta}{8}$	$1-\frac{\beta^2}{5}$	$3\left[\frac{1}{\left(\frac{\beta\pi}{2}\right)^2}\sin\frac{\beta\pi}{2}-\frac{1}{\left(\frac{\beta\pi}{2}\right)^2}\cos\frac{\beta\pi}{2}\right]$	$\frac{1}{2}\left[1-\frac{3\cos\beta\pi}{(\beta\pi)^2}+\frac{3\sin\beta\pi}{(\beta\pi)^3}\right]$
Max. Pos. Bend. Mom. $\frac{8\,M}{p_0(\beta L)^2}$ ↱	$1-\frac{2f}{3}$	$1-\frac{2f}{3}-\beta\left(\frac{1}{3}-\frac{f}{4}\right)$	$1-\frac{2f}{3}-\frac{\beta^2}{3}\left(\frac{1}{2}-\frac{2f}{5}\right)$	$2\left[\frac{1-(1-f)\cos\frac{\beta\pi}{2}}{\left(\frac{\beta\pi}{2}\right)^2}-\frac{f\sin\frac{\beta\pi}{2}}{\left(\frac{\beta\pi}{2}\right)^2}\right]$	$\frac{1}{2}\left\{1-\frac{2f}{3}+\frac{2[1-(1-f)\cos\beta\pi]}{(\beta\pi)^2}-\frac{2f\sin\beta\pi}{(\beta\pi)^2}\right\}$
Max. Neg. Bend. Mom. $\frac{12\,M}{p_0(\beta L)^2}$ ↳	$-f$	$-f\left(1-\frac{3\beta}{8}\right)$	$-f\left(1-\frac{\beta^2}{5}\right)$	$-3f\left[\frac{1}{\left(\frac{\beta\pi}{2}\right)^2}\sin\frac{\beta\pi}{2}-\frac{1}{\left(\frac{\beta\pi}{2}\right)^2}\cos\frac{\beta\pi}{2}\right]$	$-\frac{f}{2}\left[1-\frac{3\cos\beta\pi}{(\beta\pi)^2}+\frac{3\sin\beta\pi}{(\beta\pi)^3}\right]$
Fixity for Equal Max. Bend. Mom. f^*	$\frac{3}{4}$	$\frac{3}{4}\cdot\frac{1-\frac{\beta}{3}}{1-\frac{3\beta}{8}}$	$\frac{3}{4}\cdot\frac{1-\frac{\beta^2}{6}}{1-\frac{\beta^2}{5}}$	$\frac{1}{2}\cdot\frac{1-\cos\frac{\beta\pi}{2}}{\frac{1}{\left(\frac{\beta\pi}{2}\right)}\sin\frac{\beta\pi}{2}-\cos\frac{\beta\pi}{2}}$	$\frac{3}{4}\cdot\frac{1+\frac{2(1-\cos\beta\pi)}{(\beta\pi)^2}}{1-\frac{3\cos\beta\pi}{(\beta\pi)^2}+\frac{3\sin\beta\pi}{(\beta\pi)^3}}$
Load-Distribution Factor For $f\leq\frac{3}{4}$ $F_D=\frac{w}{p_0}$	1	$1-\frac{4-3f}{3-2f}\cdot\frac{\beta}{4}$	$1-\frac{5-4f}{3-2f}\cdot\frac{\beta^2}{10}$	$\frac{2}{1-\frac{2f}{3}}\left[\frac{1-(1-f)\cos\frac{\beta\pi}{2}}{\left(\frac{\beta\pi}{2}\right)^2}-\frac{f\sin\frac{\beta\pi}{2}}{\left(\frac{\beta\pi}{2}\right)^2}\right]$	$\frac{1}{2}+\frac{1}{1-\frac{2f}{3}}\left[\frac{1-(1-f)\cos\beta\pi}{(\beta\pi)^2}-\frac{f\sin\beta\pi}{(\beta\pi)^2}\right]$
Load-Distribution Factor For $f^*\leq f\leq 1$ $F_D=\frac{w}{p_0}$	1	$1-\frac{3\beta}{8}$	$1-\frac{\beta^2}{5}$	$3\left[\frac{1}{\left(\frac{\beta\pi}{2}\right)^2}\sin\frac{\beta\pi}{2}-\frac{1}{\left(\frac{\beta\pi}{2}\right)^2}\cos\frac{\beta\pi}{2}\right]$	$\frac{1}{2}\left[1-\frac{3\cos\beta\pi}{(\beta\pi)^2}+\frac{3\sin\beta\pi}{(\beta\pi)^3}\right]$

distributions are of the same form as the distributions from which they were derived. The properties of the triangular distribution are always linear in β, of the parabolic distribution are always quadratic in β, and so on. The power of β for normalizing the cosine function is always even, just as the cosine is an even function; similarly, the power of β for normalizing the sine function is always odd, just as the sine is an odd function.

Although Q_x/p_o and f^* were excepted in the previous discussion, some of the same similarities also apply to these properties. Although Q_x/p_o has not been normalized and is not of the same form as the distribution from which it was derived, nevertheless the functions of β involved in it are of the same form as in the parent distribution. It is also interesting to note that the functions of β involved in both the numerator and denominator of f^* separately are of the same form as in the parent distribution. This might well have been expected since f^* is essentially the ratio of two properties separately derived.

A detailed study of Figures 2 and 3 sheds additional light on a characteristic mentioned earlier. Figures 2 and 3 reflect the first and second integrations, respectively, of the load distribution. Indeed, Figure 2 which shows the normalized end reaction as a function of unsupported length is, by virtue of the normalizing factor, a plot of the total load (area under the load distribution) as a function of the span. It will be noted by comparing Figures 2 and 3 with Figure 1 that, although relative order of and similarity in shape to the parent distribution are maintained, these characteristics become less pronounced after integrations. This is an excellent manifestation of the well-known fact that integration is a smoothing process.

CONCLUSIONS

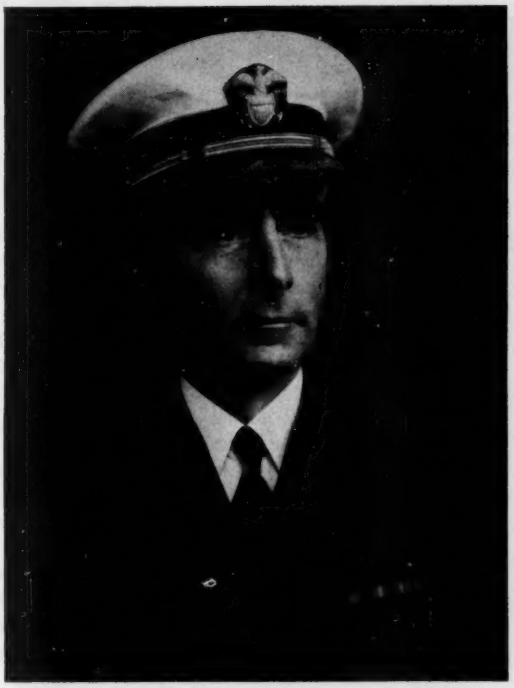
1. For the load distributions shown in Figure 1, Figures 2 through 6, inclusive, and Table I may be used to supplement similar compilations of geometric and elastic properties of beams of constant cross section. In addition, Figure 2 gives the area under the various distributions as a function of span.

2. The load-distribution factor F_D shown in Figure 6 as a function of unsupported length of beam may be used for both static and dynamic loading. If used for dynamic loading, also needed is a dynamic-load factor F_L reflecting the load-time history and Equation (1).

Regulations governing classification of nuclear ships formed the subject of a paper submitted by M. Bourceau, Chief Engineer of Bureau Veritas, at the symposium organized by the International Atomic Energy Agency at Taormina, Sicily, last November. The paper gave the impression that no rules, even provisional ones can be considered at present in view of the almost total lack of experience in the matter. Establishing technical conditions applicable to nuclear ships is a much more huge task than any of those performed until now in shipbuilding, particularly since their relevance will be confronted with the experience to be obtained from operation of the first nuclear ships. Particularly noteworthy is the suggestion that when the means provided for cooling the reactor depend on the ship's electric supply, an emergency source of electric power should be provided completely independent of the reactor, with independent wiring and capable of immediate operation. All parts of the installation which normally contains radioactive materials should be enclosed in a containment vessel of such design as to endure a maximum strength of 80 per cent of the metal yield point. Periodicity of surveys should be determined after the fourth annual survey, the first of which should be as complete as possible.

—from MARINE JOURNAL
February 1961

Rear Admiral
BRYSON BRUCE
USN (Ret)



Bryson Bruce was born in Garden Grove, Iowa, on March 20, 1886. He was graduated from Garden Grove High School before his appointment to the U.S. Naval Academy, Annapolis, Maryland, from Iowa, on May 8, 1903. Graduated on September 12, 1908. Through subsequent promotions he attained the rank of Rear Admiral on April 1, 1941. He was transferred to the Retired List of the U.S. Navy on November 1, 1946.

After graduation in September 1906, he joined the USS *Washington* in which he served until September 1911, and thereafter until February 1913 had consecutive duty in the USS *Iowa* and USS *Mississippi*. He then had instruction in electrical engineering at the Postgraduate School, Annapolis, Maryland, and Columbia University, New York, New York, receiving the degree of Master of Science from the latter in June 1914.

Admiral Bruce joined the American Society of Naval Engineers in 1914 and was elected and served as Secretary-Treasurer of the Society in 1924 and 1925.

In September 1914 he joined the USS *Kentucky*, and had additional duty until November 1914 in the battleships *Kearsarge* and *Wisconsin*. He next served successively as Engineer Officer and Executive Officer of the USS *Jupiter* during tryout of electric propulsion (1914-1916). He jointed the USS *Nevada* in January 1917 and was serving in that battleship when the United States entered World War I the following April. In May he was transferred to the USS *Illinois*, and served as Engineer Officer of that battleship until November of that year, when he was ordered in the Bureau of Steam Engineering, Navy Department, Washington, D. C., from November 1917 until October 1919, during which period the Armistice was signed. In November 1919 he reported to the Navy Yard, Mare Island, California, where he served in the Machinery Division until December 1920, when he was assigned duty in connection with fitting out the USS *California*. He served as Engineer Officer of *California* from her commissioning, August 10, 1921 until February 1922. Transferred to duty as Squadron Engineer Officer of Destroyer Squadron *Four*, Pacific Fleet, he then returned to the Bureau of Engineering, Navy Department, and from August 1922 until January 1926 had duty in the Design Division.

In March 1926 he was designated Naval Inspector of Machinery and Ordnance, Shanghai, China, in connection with the building of the river gunboats, *Guam*, *Tutuila*, *Panay*, *Luzon*, *Mindanao* and *Oahu*. He returned to duty in the Bureau of Engineering, Navy Department, from January 1929 until June 1932.

In July 1932 he reported for duty as Engineer Officer on the staff of Com-

mander Battleships, Battle Force, USS *West Virginia*, flagship. Transferred in June 1933 to duty as Fleet Maintenance Officer on the staff of the Commander in Chief, U.S. Fleet, he continued as such, attached to the USS *Pennsylvania*, flagship, until June 1934. The four succeeding years he served as Head of the Department of Marine Engineering at the Naval Academy, Annapolis, Maryland.

He had duty in the Inspection Division, Office of the Chief of Naval Operations, Navy Department, Washington, D. C. until July 1941, when he was transferred to the Administrative Division, Bureau of Ships, Navy Department. In June 1942 he was assigned duty as Chief of the newly created Office of Procurement and Material, Navy Departmen, serving in that assignment until October 1942, when he reported for duty as Supervisor of Shipbuilding and Naval Inspector of Ordnance, Cramp Shipbuilding Company.

In February 1946 he became Supervisor of Shipbuilding and Naval Inspector of Ordnance to the New York Shipbuilding Corporation, Camden, New Jersey, and while so engaged he continued similar duty at the Cramp Shipbuilding Company, Philadelphia. He served in that capacity until relieved of all active duty pending his transfer to the Retired List on November 1, 1946.

Rear Admiral Bruce has the Mexican Campaign Medal; the World War I Victory Medal; the Yangtze Service Medal; the American Defense Service Medal; the American Campaign Medal; and the World War II Victory Medal.

His official address and that of his wife, the former Louise Downs of Annapolis, Maryland, is Pines on the Severn, Hi-Vue, Arnold, Maryland.

DEATHS

It is with deep regret that we announce that since the last JOURNAL we have received notice of the deaths of the following members:

Bruce, Bryson, RADM, USN (Ret) .....Naval

Codrington, George W. Civil

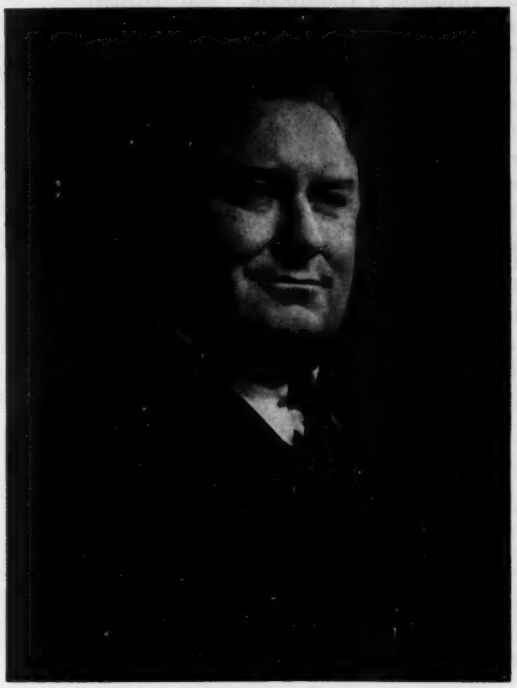
Dusinberre, G. M., CDR, USN (Ret) .....Naval

Kniskern, Leslie A., RADM, USN (Ret) ....Naval

Spencer, B. R., RADM, CD, RCN .....Associate

Weaver, G. C., RADM, USN (Ret) .....Naval

George W. Codrington Dies in Florida



George W. Codrington, retired Vice President of General Motors Corporation and General Manager of its Cleveland Diesel Engine Division, died April 25, 1961, in Daytona Beach, Florida. He was 74.

Services were held April 28, 1961 at the Hardage and Son Funeral Home in Jacksonville, Florida. Burial will be in Jacksonville.

Mr. Codrington was born at Palatka, Florida on December 22, 1886. He received his early education in the schools of Jacksonville, Florida and from tutors.

In 1903 he was employed by the Jacksonville Ferry Company as Marine Engineer and until 1912 he held similar positions with the R. C. Ross Company and the Galloway Coal Company. From 1912 to 1914 he was Engineer on various ships and in 1914 and 1915 he was Chief Engineer on the yachts "Everglades" and "Paragon." In 1917 he joined the Winton Engine Corporation in Cleveland, Ohio as Marine Superintendent. Mr. Codrington was appointed General Manager of the Winton Engine Corporation in 1919, Vice President in 1925 and President in 1928. In 1930 General Motors acquired Winton as a subsidiary and Mr. Codrington continued in the capacities of President and General Manager. In 1938, when Winton Engine became Cleveland Diesel Engine Division of General Motors Corporation, Mr. Codrington took the title of General Manager. He was elected a Vice President of General Motors on January 5, 1942.

Mr. Codrington joined The American Society of Naval Engineers in 1940 and was a strong and active supporter of The Society until his health prevented in the last few years. He was a member of many other Societies and clubs in his home city of Cleveland, New York, Washington and other cities.

He held directorates in the Addressograph-Multigraph Corporation, Cleveland, Ohio; National Acme Company, Cleveland, Ohio; and Allied Products Company, Detroit, Michigan. He was a trustee of the Fairview Park Hospital, Cleveland, Ohio.

Mr. Codrington retired from General Motors Corporation in December 1952, after more than 35 years of service with General Motors and Winton Engine Corporation, predecessor of the Cleveland Diesel Engine Division.

Mr. Codrington is survived by his wife, Mrs. Gladys M. Codrington.

BOOKS RECEIVED

"The Radio Amateur's Handbook," 38th edition, by the headquarters staff of The American Radio Relay League. The 1961 edition of the standard manual of amateur radio communication, published by The American Radio Relay League, West Hartford, Connecticut. 584 pages, $3.50.

"Dictionary of Mechanical Engineering," by Alfred DelVecchio. A comprehensive dictionary of prime definitions in the fields of architecture and engineering, published by Philosophical Library, Inc., 15 East 40th Street, New York 16, New York. 346 pages, $6.00.

"The Lightning Book," by Peter E. Viemeister. The nature of lightning and how to protect yourself from it, published by Doubleday and Company, Inc., Garden City, New York. 316 pages, $4.50.

"Bulletin de L'Association Technique Maritime et Aéronautique." A compilation of technical papers in the marine and aeronautical fields presented to the association in 1960, published by Association Technique Maritime et Aéronautique, 47 rue de Monceau, Paris, France. 662 pages. (In French.)

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"Transactions of North East Coast Institution of Engineers and Shipbuilders," Volume 76, Session 1959-60, edited by the secretary, published by North East Coast Institution of Engineers and Shipbuilders, Newcastle Upon Tyne, Bolbec Hall, England. 536 pages.

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In 1837, the photovoltaic effect was discovered which proved that when a juncture of dissimilar metals is exposed to light, an electrical current will flow across the juncture. Taking this old discovery and applying modern technology to it, we have the Hoffman Solar Cell. The ultrapure silicon is made moderately impure with the introduction of arsenic under very carefully controlled manufacturing conditions. A single crystal of silicon, six to eight inches long and one inch or more in diameter, is grown. The single crystal is then cut into small rectangles—the cells on Courier are 1 by 2 centimeters. The cells are then heated and boron is made to diffuse into their surface.

When sunlight strikes on the boron surface of the solar cell, the light energy—called photons—disturb the electron structure of the crystal, which, in turn, upsets the electronic structure of the silicon-arsenic combination into which the boron has been diffused. All this movement of electrons between boron and silicon gives rise to an external voltage on the cell that has only to be connected into an electrical circuit. Sunlight acts as a current generator and because only electrons are moving within the silicon cell, nothing is lost and the process can continue as long as there is sunlight.

—HOFFMAN ELECTRONICS CORP. NEWS RELEASE

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The Society takes great pride in announcing that the following have joined its ranks since the publication of the February 1961 issue of the JOURNAL.

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"The Radio Amateur's Handbook," 38th edition, by the headquarters staff of The American Radio Relay League. The 1961 edition of the standard manual of amateur radio communication, published by The American Radio Relay League, West Hartford, Connecticut. 584 pages, $3.50.

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Consideration of the factors which make it difficult to obtain accurate and reliable data from ships' machinery during trial runs has shown that a two-fold program to develop methods and instruments for automatically logging pertinent data would offer promise of a distinct improvement over the methods used to date while at the same time serving as one of the steps toward computer control of ship machinery. BUSHIPS, therefore, established this joint project in which the Naval Boiler and Turbine Laboratory and the David Taylor Model Basin are cooperating in the development of a data logging system to be used for collecting heat balance and fuel economy information from ships' machinery during trials.

NBTL is responsible for the specification of primary elements and their installation and operation in a machinery plant available at the Laboratory. The responsibility for the actual data logger rests with DTMB.

Compatibility of the selected primary elements with the proposed data logger has been determined; the units have been purchased, tested, and are now installed in the machinery plant where, in conjunction with the logger expected next month from DTMB, a series of runs will be made to evaluate the complete system before installation aboard ship.

The final end product is expected to be a compact system, simple to transport, and capable of easy installation and removal, which will be a prototype for future expansion into a system which can obtain all the information desired from the machinery during trials but so unitized as to permit the use of separate components for limited project work where less extensive information is sought.

—from NAVAL BOILER AND TURBINE LABORATORY BRIEFS
January 1961

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NAVAL MACHINERY SINCE THE WAR

The late war changed British naval machinery practice just as profoundly as has the "nuclear age" radically altered naval thinking generally—and with it design and construction policy. Sir Alfred Sims naturally included the machinery side in his most interesting Andrew Laing Lecture although of necessity he went over, in briefer fashion, a good deal of the ground covered by Vice Admiral Sir Frank Mason (then Engineer-in-Chief of the Fleet) in his Parsons Memorial Lecture of 1956. It may be recalled that Sir Frank's notable survey was also given in Newcastle before the members of the North East Coast Institution.

The last war demonstrated to British naval experts, including engineering ones, that the Americans could teach us a good deal about naval machinery. The design and performance of their steam turbines was superior to ours, and their ships were operationally more efficient as a consequence. Sir Alfred reminded us that the ***Daring***-class machinery design was a direct result of the salutary experience of the war years; and it says much for all concerned that quick use was made of the basic design information supplied by the Americans, energetically translated into YEAD 1 by Yarrow, English Electric, Pametrada, and the Engineering-in-Chief's department. These early postwar efforts were real achievements, but Sir Alfred was right to draw particular attention to the later Y 100 frigate machinery. The Korean war accelerated the design and development work on this improved project. The machinery was produced with commendable speed and the design has proved a real success. It must have given those responsible satisfaction to read the Director's appreciative reference to this piece of work.

The gas turbine has received close study and encouragement by the Admiralty and Sir Alfred Sims expressed the opinion that the so-called gas turbine boost development has been the most important naval machinery advance sponsored by the Admiralty in the past five years. He was right, of course, to say that this term is a misnomer. It is better described as a form of combination machinery; the Americans graphically call it C O S A G—combined steam and gas, which is correct nomenclature. The boosting gas turbine of these installations can be used, it may not be appreciated, for maneuvering as well as propelling the vessel when the steam plant is shut down. Prototype trials have had the object of making it as reliable as the more conventional arrangement. H.M.S. ***Ashanti*** will shortly demonstrate to British naval engineers whether the work of the last five years has justified their hopes that this type of machinery has the advantages which theoretical consideration suggest it sould have in practice.

—THE MARINE ENGINEER AND NAVAL ARCHITECT

I'LL HEAR FROM YOU BY MOONLIGHT

When Solar eruptions disrupted global radio communications in November, Navy pressed its Communications Moon Relay System—which had been on part time evaluation test—into service, reports Developmental Engineering Corp., designer and builder of the CMR system. According to the firm, the UHF radio signals, bounced off the moon, kept information flowing between Hawaii and the Pentagon, messages moving over four teletype channels each way at the rate of 240 words a minute, covering 480,000 miles in two-and-a-half seconds.

—Research/Development Magazine

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MAY, 1961

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